TECHNOLOGY AND MATHEMATICS TEACHING AND LEARNING: USING FLIPPED INSTRUCTION TO TEACH MIDDLE SCHOOL MATHEMATICS

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ABSTRACT

Raelysha Butler James: Technology and mathematics teaching and learning: Using flipped instruction to teach middle school mathematics
(Under the direction of Rita O'Sullivan)

Advances in technology have changed the world. Finding effective means for incorporating technology in the learning environment is important to educators. One of the newer strategies is blended learning, which is also known as flipped instruction. With this mode of instructional delivery teachers maintain the role of instructional leader but direct classroom instruction and homework are flipped. The belief is that work typically done as homework (e.g., problem-solving) is better undertaken in class with the teacher's guidance and students can watch instructional videos outside of direct instruction in the classroom.

Although flipped instruction has gained considerable popularity in K-12 and college classrooms over the last decade, very little empirical research supports its effectiveness, especially with younger students, because much of the available literature is anecdotal. The limited numbers of actual studies conducted on flipped instruction in middle school do provide some foundation for its use

The intent of this study was to investigate how the use of flipped instruction impacted teaching and learning of mathematics in middle grades classrooms. Three teachers in a public Montessori school utilized a flipped learning approach with their multi-age 7th and 8th-grade mathematics classes. The goal of this study was to examine 7th-grade students' responses to this mode of mathematics instruction as a specific use of technology.

Research questions for this study focused on three topics:

1. How does the use of the flipped learning affect teaching and learning in a middle grades classroom?
2. How does the use of flipped learning instruction affect student engagement and motivation?
3. In what ways, if any, does flipped learning impact the "gaps" in student achievement?

Observations, surveys, interviews, and standardized test scores were used to answer these questions. Findings suggest that flipped learning did affect how teachers and students engaged in mathematics learning. It also found that for mathematics, students reduced anxiety, increased ability to focus, and enhanced their self-efficacy as a math student. The final research question, which examined how flipped instruction impacted the achievement gap between white and non-white students, found that this method did not appreciably help close the achievement gaps in student performance.

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CHAPTER 1: INTRODUCTION

The quality of mathematics teaching and learning in the United States has been a concern for numerous decades (National Mathematics Advisory Panel [NMAP], 2008). *A Nation at Risk*, published in 1983, focused national attention on American students' mediocre academic performance and the possible long-term implications for the country (U.S. Department of Education, 1983). In response, the National Science Foundation funded numerous standards- based curriculum projects in the 1990s. Included in those projects were Everyday Mathematics and Mathematics Trailblazers for K-5; Connected Mathematics and Mathematics in Context for grades 6-8; and Contemporary Mathematics in Context and Math Connections for grades 9-12. Commissioned by the U.S. Department of Education, the NMAP (2008) reviewed research. It recommended techniques for improving mathematics teaching and learning in a report entitled Foundations for Success. Combining the recommendations from the aforementioned report and relevant research and publications of the prior 30 years spawned the Common Core State Standards in Mathematics (CCSSM; National Governors Association Center for Best Practice, 2010). The CCSSM, adopted by 45 states, were designed to identify, sequence, and standardize the mathematics curriculum for K-12 students in the United States.

Many of the concerns about mathematics teaching and learning stem from international comparisons of student achievement. Trends in International Math and Science Studies (TIMSS; 2016) reported that the United States ranked ninth among 43 countries in eighth-grade math scores. Countries that scored higher on the TIMSS math assessment included Singapore, Korea, Chinese Taipei, Hong Kong-CHN, Japan, the Russian Federation, Canada, and Ireland (National Center for Education Statistics, 2016). A comparison of the previous administration of the TIMSS eighth-grade math assessment in 2007 with the 2011 test showed no measurable gain among the U.S. average eighth-grade mathematic scores. However, between 2011 and 2015 administrations, U.S. average eighth-grade math scores increased more than in the previous 12 years. Figures A1 and A2 in Appendix A represent data taken from the 2016 TIMMS report.

To add to the challenge of teaching students who are behind the international standards, Goldberger and Bayerl (2008) noted the current high-stakes testing focus has widened the performance gap among economically disadvantaged and diverse populations of students. Chait, Goldware, Housman, and Muller (2007) shared that current math results, in particular, have presented serious concerns about student abilities as they progress into the secondary math courses. These researchers found that the level of complexity and steps needed to master concepts have increased in rigor and difficulty. Consequently, they concluded, many students have exhibited lower math achievement scores.

In addition to concerns about academic performance, recent years have seen increased efforts to align classroom technology usage with “real world” usage. The 21st century has seen dramatic changes in the ways people access and use digital technology. Technology is pervasive in our lives. It has transformed modern living. However, when the ways in which technology is being used in education are examined, there is a severe disconnect between in-school use and out-of-school use (National Education Technology Plan, 2010). One of the challenges educators face concerns how to engage best and meet the needs of students living in a world of almost ubiquitous information and communication-related digital technologies (e.g., Internet, handheld devices, cell phones, gaming consoles). Children growing up today are often very comfortable using these technologies for entertainment, information gathering, and communicating with each other, giving rise to what Prensky (2006) referred to as the digital native. The ways that new information and communication technologies are used outside of school suggest that children today are creating understandings and knowledge in new and different ways (Spires, Lee, Turner, & Johnson, 2008). Mathematics education reform efforts have just begun to acknowledge this characteristic of modern-day learners.

Unfortunately, many teachers and classrooms do not reflect adaptations to pedagogy based on this knowledge about technology use. Making the change is not a simple endeavor. It has only been in the last 20 years that the use of calculators became a regular and excepted practice in K-12 classrooms. The use of tools such as interactive whiteboards, presentation software, graphing software, and digital games are expected in modern classrooms. Yet, little has been done to assure the effective implementation of these tools (National Education Technology Plan, 2010). Utilization of new technologies, such as computer-assisted instruction, requires a paradigmatic shift in the traditional way mathematics has been taught (Aydm, 2005). New information technologies debut regularly, and teachers need guidance on how best to integrate them for classroom use. A potential key to bridging the gap in acquiring the mathematical skills needed for the 21st-century learner is the development of technology-based methods of instruction that address their cognitive styles as well as increase students' engagement, collaboration, and active learning (Prensky, 2006, Silk, Higashi, Shoop, & Schunn, 2010). Finding effective means for incorporating technology in the learning environment is one of both education researchers' and teachers' goals.

Blended learning models combine digital learning with face-to-face learning opportunities. Flipped instruction is one of the more well-known blended learning models. There is no single specific definition for flipped instruction. Numerous variations of this strategy with different names have been used in the past and are currently in use. Although not a new concept, this instructional strategy has recently increased dramatically in popularity. Although the name of the strategy and how it is implemented differs slightly by context, flipped instruction is generally utilized to increased teacher-student and student-student contact by changing the dynamic in which information is presented. In its most basic form, flipped instruction consists of prerecorded lecture content, which is made available online for students to access outside the classroom. Students watch these videos as homework before class, receiving the content lecture on their own time (U.S. Department of Education, 2017). This allows class time to be spent on other activities, such as group projects, problem-solving, and discussion. Research focusing on flipped instruction reveals (Baker, 2000; Bergmann & Sams, 2012; Kim, Byun, & Lee, 2012; Lage, Platt, & Treglia 2000) impacts that include:

- meaningful activities instead of busywork,
- teacher as tutor,
- increased student interaction,
- increased teacher-student interaction,
- a focus on learning, not just behaving in a “school” way,
- immediate feedback for students,
- mastery learning,
- make technology integral,
- just-in-time instruction, and
- other including improved student attitude and improved teacher attitude.

Much of this same research has also identified challenges in implementing this strategy. The challenges include a lack of commitment from students in viewing videos prior to class, videos that provide poor quality direct instruction, videos that fail to engage students, and access to the technology needed to view videos outside of the classroom.

Problem Statement

As the revolution of modern technology continues to transform society, the landscape of education is recreated and restructured (Bartolini Bussi & Borba, 2010). These changes provide teachers a multitude of new media devices, software applications, and unlimited Internet resources that research has shown to be a benefit for student learning (Cheung & Slavin, 2011; Ertmer & Ottenbreit-Leftwich, 2010). Technology is increasingly being used to personalize learning, empowering students to exercise more control over what and how they learn and at what pace (U.S. Department of Education Office of Educational Technology, 2017).

A consistent barrier to technology integration into the teaching and learning of mathematics has been teacher preparation. Chen (2008) explored the relationship between teachers' pedagogical beliefs and technology integration. Findings indicated inconsistency between the teachers' expressed beliefs and their practices. Despite studies documenting the effectiveness of technology to support student learning, the 2017 National Technology Plan Update states that many teachers have not been prepared to teach with technology in their teacher preparation programs. In addition, many teachers do not have access to professional learning to support teaching in a technology-enhanced environment. Poor preparation is a barrier to full integration (Ertmer & Ottenbreit-Leftwich, 2010).

One of the significant changes in the fields of education and industry is the nearly constant technological advancement. New technologies are transforming all facets of modern life. Nevertheless, there remains a disparity among teachers' instructional proficiency and their level of technology use both in and out of the classroom (Bray & Tangney, 2017; Ertmer & Ottenbreit-Leftwich, 2010). Research has found limitations of educational technology use among teachers suggest that more research is needed to learn how to implement technology and support teachers in ways that are easily understood, efficient, effective, and can be adapted to different learning environments. Past research suggests that technology integration can be useful in finding more engaging methods to teach students in mathematics (Carreira, Clark-Wilson, Faggiano, & Montone, 2017; McCulloch, Hollebrands, Lee, Harrison, & Mutlu, 2018).

Epson et al. (2010) determined that a highly structured integration of technology in math, along with effective teacher training and support, can yield positive results in student achievement. Other researchers have explored the varied usage of digital technologies in relation to teaching mathematics, contending that such methods will evolve and improve cognitive processing for students (Moreno-Armella, Hegedus, & Kaput, 2008). Bergmann and Sams (2012) articulated that math classes, in particular, are opening up to higher levels of computational thinking and inquiry when integrating technology into mathematics instruction. Given these points, the expansion of research, based on technology usage in math education is essential. Moreover, research about the specific technologies and their potential for student engagement may serve to add to the dialogue regarding the integration of digital resources into instruction.

Implications from research to date suggest that using a flipped learning model can increase not only student achievement but also student interest and motivation. Research also implies “flipping the classroom” can significantly improve outcomes for English language learners, students with learning difficulties, and students of color, which can help reduce the achievement differences between different demographics (Martin, Arrambide, & Holt, 2016).

Mathematics educators are invested in improving the quality and effectiveness of mathematics instruction and meeting the needs of 21st-century learners, which require strategies that engage and incorporate technology. Utilizing technology to help provide instruction could also help schools address both the time and the resource/budget constraints that many mathematics teachers face as they strive to implement curriculum effectively.

Statement of Purpose and Research Questions

The intent of this study was to investigate how the use of flipped learning impacts the teaching and learning of mathematics in middle-grade classrooms. A group of four teachers utilized a flipped learning approach with their multi-age seventh- and eighth-grade mathematics classes. The target population for this study was minority students new to flipped instruction in mathematics. This study examined middle school students' responses to mathematics instruction, which integrates a specific use of technology. Several sets of standards were used in this examination, including best instructional practices, as identified by the National Council of Teachers of Mathematics (NCTM), learner outcomes and mathematical practices as identified by the CCSSM, and technology implementation of the replacement amplify transform (RAT) framework.

The research questions for this study focused on three distinct topics:

1. How does the use of the flipped learning instruction model affect teaching and learning in middle-grades classrooms?
2. How does the use of flipped learning instruction affect student engagement and motivation?
3. In what ways, if any, does flipped learning impact the "gaps" in student achievement?

Significance of the Research

Improving learner outcomes in mathematics is vital for both students' future educational and economic purposes. Without question, the teacher is the most significant factor impacting what happens in the classroom. Technology can be a valuable tool for transforming teacher practice, which transforms the learning environment and experience. In many schools and districts, there is limited time for teacher professional development. Technology tools can provide a vehicle for teacher collaboration and learning, including cognitive development. This collaboration can lead to self-directed teacher change toward a more inclusive, diversified classroom, able to meet the cognitive needs of all students (Haggar, Kelly, & Chen, 2017; Linder, 2017). If the teacher perceives that technology provides a catalyst for students to access all forms of mathematics, including complex mathematical ideas, then given adequate instruction, time, and support with the technology, the teacher may be better able to make decisions about the successful practices that directly affect student achievement (McCulloch et al., 2018). The abundance of technology tools currently available could have the power to transform how teachers view all their students and how they teach them for greater mathematical understanding. Instruction that utilizes technology may be one way that learning tools create an environment for teachers to help negotiate individual needs for learning and teaching, and personalize the learning experience for students (Faggiano, Ferrera, & Montone, 2017).

Theoretical Framework

The theoretical framework used for this study was based on two models utilized to examine technology usage in mathematics teaching and learning. The first was the mathematics technological pedagogical content knowledge (TPACK) standards developmental model (Niess et al., 2009). TPACK identifies the nature of knowledge required by teachers to integrate technology into their teaching while simultaneously addressing the complex nature of teacher knowledge (Koehler, Mishra, & Cain, 2013). The TPACK framework focuses on the knowledge that lies at the intersections of pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK (Koehler et al., 2013). Mathematics is the content of the MTPACK model.

Stipulations of the Methods Used in the Study

This study focused on an instructional unit in four middle-grade mathematics classrooms taught by four different teachers. All of the teachers in the study taught the same content at the same time and planned collaboratively. All students were given an attitude survey and a content-based assessment both before and after instruction. Classroom observations, lesson plans, student interviews, teacher notes, and teacher interviews also were part of the data collection.

Key Assumptions of the Study

For this research, all participants who answered the questions proposed to them did so with truthfulness and sincerity. The questions utilized in this research were designed to solicit authentic and meaningful responses from the participants that adequately described their own experiences with flipped instruction. The researcher used the surveys, assessments, interview process, and classroom observations to interpret the participants' responses to establish specific themes among the participants.

The following assumptions were made in this research:

- Written permission and consent would be given by all participants to be interviewed, including parents of students who participated.
- The name of participants, school, and district all would be kept confidential in this research, all participants would be kept anonymous, and privacy would be protected.
- Participants would not be influenced in any way concerning their responses and would answer questions honestly.
- The researcher would implement all aspects of this study, objectively and factually.
- Data presented about campus demographics would be accurate and current based on the most recent state documents.

Limitations of the Study

While every effort was made to ensure a thorough qualitative study during this research, a few limitations were anticipated and need to be discussed. First, the duration of the study of the implementation of flipped learning was limited to a portion of the school year, and this research would have benefited if there were more time to allow participants to become acclimated to this model. Second, the effect of digital media on student learning may be perceived as a novel experience and possibly influenced student responses during their interviews. Third, the balance of experience among the four teachers participating was unequal. One was a novice teacher, and his or her limited experience might have affected the implementation of the blended learning model. Last, the participating students were considered students of diverse backgrounds, including low socioeconomic status and bilingual abilities, which might have influenced their perceptions of the flipped model. Thus, the student sample might not be fully representative of a general population.

Definitions

Blended learning. In a blended learning environment, learning occurs online and in-person, augmenting and supporting teacher practice. Blended learning often allows students to have some control over time, place, path, or pace of learning. In many blended learning models, students spend some of their face-to-face time with the teacher in a large group, some face-to-face time with a teacher or tutor in a small group, and some time learning with and from peers. Blended learning often benefits from a reconfiguration of the physical learning space to facilitate learning activities. It provides a variety of technology-enabled learning zones optimized for collaboration, informal learning, and individual-focused study (U.S. Department of Education, 2017).

Flipped learning model. A model of instruction in which digital technology is used to move teacher instruction outside of the classroom environment, allowing students to view direct instruction anywhere and anytime. This shiftallows instructors to maximize class time to foster higher student engagement through collaborative learning, problem-solving, practice skills, and more face-to-face time between teachers and students (Bergmann & Sams, 2012; Fulton, 2012; Hamdan, McKnight, & McKnight, 2013; Tucker, 2013).

Phenomenology. The study of people who share a collective experience or phenomenon in which each describes his or her individual perceptions of that event resulting in a common theme or essence of that experience (Creswell, 2013).

Technology. Technology is often used as a generic term to encompass all the technologies people use. For this document's purpose, the term was used to represent the electronic and digital tools used for communication, entertainment, data manipulation, and computation.

Technology integration. Integration occurs when classroom teachers use technology to introduce, reinforce, extend, enrich, assess, and remediate student mastery of the curriculum.

Summary and Organization of the Study

In Chapter 1, a brief overview of current theories on the use of technology in mathematics teaching and learning was provided. This chapter also explicated the foundations for research on flipped learning, including the background of attitudes and perceptions toward technology in teaching mathematics, specifically of the flipped learning model including background, problem statement, a theoretical framework, statement of the purpose, research questions, rationale, significance of the study, assumptions, limitations, definitions of terms, and summary. In Chapter 2, a review of the literature examines effective mathematics instructionand technology integration in mathematics teaching and learning. Next, the reviewpresents research on flipped learning based on the history, characteristics, benefits,and effectiveness with a variety of different learners. Chapter 3 presents the methodology, including the research design, setting, participants, data collection, and treatment of data.

CHAPTER 2: LITERATURE REVIEW

Introduction

Efforts to reform the teaching and learning of mathematics in the United States have become more intense and centralized over the past three decades. In 2010, the National Governors Association Center for Best Practices (NGA) and Council of Chief State School Officers, in collaboration with mathematics researchers, mathematics educators, the NCTM, and other vested parties introduced the CCSSM. These standards were developed to resolve significant issues related to the mathematics to be taught in grades K-12, and detail precisely what should be taught in grades K-8. The CCSSM was intended to articulate not just what students are to learn, but also what they should be able to do with that learning as defined in the Standards for Mathematical Practices. The development of a set of research-based mathematics teaching practices evolved as a result of that work. Included in those teaching practices were recommendations for integrating technology in the teaching and learning of K-12 mathematics.

The Organization of the Literature Review

Improving the quality of mathematics teaching and learning is a goal for many mathematics teachers and educators. Mathematics reform has been the subject of an abundance of research over the past 60 years, much focusing on constructivist strategies. Therefore, this literature review begins with an overview of the research on effective mathematics instruction. Some focus was given to the research related to middle-grade mathematics, as this study took place at that level. The utilization of technology as an essential component of mathematics instruction and the related literature are reviewed next. Determining the exact nature of technology usage and its impact on teaching is the next topic covered in this chapter, necessary given that this study focused on the pedagogies evolving to integrate technology into learning and support the development of 21st-century skills. The recommendations for technology usage that enhance learning are specific, and some research on these recommendations and the tools that have been created to evaluate technology use are provided. One purpose of this research study was to explore seventh-grade math students' perceptions and those of their teachers about their participation in a flipped learning environment. The final section of the literature review focused on flipped learning, the effectiveness of the flipped model, perceptions of flipped learning, and limitations and critiques of flipped learning.

Effective Mathematics Teaching Practices

Though some characteristics define good teaching in general, research has detailed some of the differences among disciplines to identify the specific practices most effective in supporting student learning (Ball & Forzani, 2011). The effectiveness of mathematics teaching and learning is a function of teacher content and pedagogical knowledge, work with and focus on students, and of students' engagement with appropriate assigned tasks (Kilpatrick, Swafford, & Findell, 2001). The interaction of mathematical content with teachers and students determines the quality and effectiveness of teaching and learning. Although the term PCK is one that has been used to describe the knowledge needed to teach, the model presented by Ball, Thames, and Phelps (2008) attempted to more precisely identify the nature and types of knowledge needed to teach mathematics. Figure A2 and Table A1 in Appendix A represent their framework for the knowledge needed for teaching math.

Effectiveness in teaching mathematics is also defined as providing consistent support for authentic applications of mathematics (Strickland & Coffland, 2004). The apparent goal for students is to learn authentic mathematics skills and strategies and be able to apply the mathematics that they have learned in their everyday lives. The NCTM is an organization that has worked assiduously since the 1980s to merge the research on mathematics education into classroom instructional practices. As stated in *Professional Standards for Teaching Mathematics*, "Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well" (NCTM, 1991, p. 20). Data have shown that students who have teachers who use reform pedagogy practices score higher on standardized tests than students who do not (COMAP, 2003; Griffin & Callingham, 2006; McKinney, Chappell, Berry, & Bythella, 2009).

More recent research and reform efforts have also provided a set of practices to guide mathematics teaching in conjunction with the learning practices. In *Principles to Actions, PtoA; Ensuring Mathematical Success for All* (National Council of Teachers of Mathematics, 2014), NCTM presented a research-informed framework that identified specific teaching practices associated with effective mathematics instruction. According to NCTM, "effective" mathematics instruction "engages students in meaningful learning through individual and collaborative experiences that promote their ability to make sense of mathematical ideas and reason mathematically" (National Council of Teachers of Mathematics, 2014, p. 7). *PtoA* identifies eight processes that represent a core set of high-leverage practices and essential skills necessary for good mathematics teaching (Ball et al., 2008; NCTM, 1991, 2000). A comparison of the Ball et al. framework with the effective teaching practices from NCTM demonstrates the degree to which research supports the essential characteristics of good mathematics instruction. Table A2 in Appendix A (National Council of Teachers of Mathematics, 2014, p. 10) illustrates the identified teaching practices. These practices can be characterized by strategies that fall into one of three categories.

- ensuring student engagement in learning,

- understanding the content; focusing on what students are to learn, understand, and be able to do with their knowledge, or
- making the connections; elucidating the connections between various representations.

The connection between these categories and the NCTM teaching practices is shown in Table 3.

Though each of the teaching practices from NCTM has been placed within a broad category of this structure, implementing these practices can fall within more than one category. This schema provides an efficient structure for organizing the tasks and responsibilities related to teachers' work while emphasizing the interconnectedness of these practices.

The classroom and classroom interactions represent the arena for teaching practices. A considerable body of research has shaped the current view of "good" mathematics instruction and classroom environment, representing a change in basic assumptions from what has been held traditionally. The environment is a crucial component of the implementation of mathematics instruction. An ideal classroom environment is one that is a learning community that utilizes mathematical discourse to allow students to collaborate and explore rigorous tasks, communicate, and evaluate each other's thinking and reasoning, and develop a positive disposition toward mathematics (NCTM, 1991, 2000). Effective teaching practices can facilitate the creation and management of this environment. Research has shown that the development of classroom learning communities can be linked to specific teacher practices (Hufferd-Ackles, Fuson, & Sherin, 2004).

Both the teacher and the students play a role in creating an environment that supports productive mathematical discourse. Hufferd-Ackles et al. (2004) have named this desired environment a Math Talk learning community. They defined it as "a classroom community in which the teacher and students use discourse to support the mathematical learning of all participants" (Hufferd-Ackles et al., 2004, p. 82). The version of their framework referenced here is shown in Figure A3 in Appendix A. This version of the framework was adapted from two earlier versions and was created in collaboration with Susan Friel. This version includes descriptors of the teachers' actions and the student actions at each of the four levels and the shifts that happen as the community advances. The model includes five components that influence the classroom environment. These components impact the nature of the learning community and offer four different levels of participation of the teacher and students through which a community can advance.

The Math Talk framework demonstrates the interaction of teacher practices necessary to create an environment that best fosters student learning. In the optimal environment, students work on authentic tasks, explore and discuss the mathematics among themselves, and share their findings and conclusions. The teacher acts as a coach who supports and guides student work, rather than supplying fixed strategies or solutions for students to memorize.

Recent research on the teaching and learning of mathematics supports a socio-constructivist perspective that promotes a specific learning environment (Hufferd-Ackles et al., 2004). The role of the teacher in the modern classroom is that of the facilitator of learning. In this environment, the interactions between students and the teacher and students provide opportunities for students to learn by exchanging ideas and exploring their thinking and the thinking of others. Learning is a collaborative effort, and communication is a critical component of the process. Social interactions can become problematic for middle-school-age students. The use of teaching practices associated with creating a learning community supports their need for social interaction and provides a frame for appropriate communication. The validation of their work and effort also promotes engagement (NCTM, 2014).

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One of the specific practices of an effective mathematics teacher is facilitating discourse. Research has shown that successful facilitation of productive classroom discourse requires improvisation and an extensive network of content knowledge, pedagogical knowledge, and knowledge of students as learners that are interwoven (Stein, Engel, Smith, & Hughes, 2008). To facilitate effective discourse, teachers must consider the mathematics that they want students to learn and their expectations for how that learning will develop. They must then select student work and prepare questions that will facilitate the class's development of conceptual understanding.

Utilizing their research and the work of others, Smith and Stein created a set of strategies to assist teachers in facilitating productive mathematical discussions. Their five practices (Stein

& Smith, 2011) serve as a guide for effectively using student responses in whole-class discussions. Teachers utilizing these five practices are better prepared to promote student engagement, sense-making, and conceptual understanding as a result of discussions.

- anticipating student responses prior to the lesson,
- monitoring students' work on and engagement with the tasks,
- selecting particular students to present their mathematical work,
- sequencing students' presentations in a specific order for discussion, and
- connecting different students' responses and connecting the responses to key mathematical ideas.

Research indicates that utilizing these practices can support and promote quality classroom discussion by providing the opportunity for the teacher to plan for what happens in the classroom. Planning increases the likelihood of achieving the desired learning outcomes. Research has shown that student learning is most significant in environments where tasks consistently encourage high-level thinking and reasoning. However, research has also shown that tasks requiring high cognitive demand are the most difficult to implement well and often transform into less challenging tasks during implementation (Stein, Grover, & Henningsen, 1996). Successfully using the five practices depends on implementing a cognitively demanding task with multiple possible responses and having clear, well-defined instructional goals, both of which are supported by teachers' understanding of their students' current mathematical thinking and practices (Stein et al., 2008; Stein & Smith, 2011; Smith, Hughes, Engle, & Stein, 2009).

Posing purposeful questions at the appropriate time is one way that teachers support students as they work through cognitively demanding tasks and is another valuable tool in facilitating discourse (Chapin, O'Connor, & Anderson, 2013; Clark, 2004; Stein & Smith, 2011).

Questions are also an excellent formative assessment tool that can provide teachers with insight into the depth of students' understanding of concepts and any misconceptions. A myriad of research addresses differences in types of questions and purposes for questioning (Clark, 2004; Cross, 2009; Kazemi & Hintz, 2014; Schuster & Anderson, 2005; Manouchehri & Lapp, 2003; Simpson, Mokalled, Lou, & Che, 2015).

Questioning is an effective strategy for helping students learn mathematics. Different types of questions provide different types of information that can be used to assess and gather information about student thinking and understanding. Effective teachers use this information to help support student development of mathematical ideas and concepts. Just as importantly, research suggests that effective instruction employs patterns of questioning designed to focus on and extend student understanding of mathematical ideas and support their sense-making as a part of the discourse.

Ensuring and supporting student engagement in mathematics learning also includes creating an environment that supports productive struggle. Research supports the theory that struggling to make sense is a necessary element of learning mathematics with understanding (Warshauer, 2014). Warshauer defined productive struggle in mathematics as a student's "effort to make sense of mathematics, to figure something out that is not immediately apparent" (Warshauer, 2014, p. 377). In contrast, unproductive struggle occurs when students "make no progress toward sense-making, explaining, or proceeding with a problem or task at hand" (Warshauer, 2014, p. 377).

The ability to support and engage students in productive struggle requires the use and existence of other instructional practices. Creating a learning environment that is conducive to struggle and supports the use of discourse is necessary. Employing high cognitive demand tasks and implementing them with fidelity is another high-leverage practice that must accompany productive struggle. Being able to support students while they struggle without lowering the cognitive demand of the task requires the ability to pose good questions in a pattern that will focus instead of funnel student thinking is also a key element. As a component of discourse, emphasizing the inevitability of errors and confusion as a natural part of learning, while also using mistakes and misconceptions as positive learning opportunities, are other ways that teacher actions can support the development of student thinking and efficacy. Again, because of where they are developmentally, middle school students need to be encouraged to overcome their self-doubt and identity development issues when faced with challenges (Feinstein, 2009). Utilizing research-based discourse strategies is a means of encouraging student persistence.

Research also presents other strategies to help support productive student struggle in mathematics. Teacher actions related to productive struggle include encouraging student efforts, providing time for students to struggle, posing guiding questions, and acknowledging the struggle and the importance of struggle in learning mathematics (Warshauer, 2015). Research has also shown that students' goals and beliefs about learning are related to their mathematics performance.

Goals are essential in a mathematics classroom because they help identify the specific learning that is to take place. Clear goals determine what is to be taught and understood (Stein & Smith, 2011). The practice of setting goals allows teachers to use content and pedagogical knowledge to select appropriate instructional activities. In the current standards-based perspective, goals describe the concepts, methods, ideas, and understandings that students should obtain as a result of instruction. These goals also identify the mathematical practices that students should use and refine (NCTM, 2000). Essential questions, unit goals, and lesson goals provide a means for students and teachers alike to monitor achievement and identify learning needs.

Evidence of student thinking and learning is a vital component of any instructional cycle. Without evidence, there is no indication of how instruction has impacted students' understanding of mathematical ideas. If clear, well-defined learning goals are the starting point for effective instruction, evidence of student thinking is needed to assess progress toward the goal (Wiliam, 2003). Evidence of student thinking should be collected continually, which provides teachers the best opportunity to clarify misunderstandings and correct misconceptions (Smith, Bill, & Hughes, 2008). Formative assessment is the process of eliciting and interpreting evidence about what students have learned and then using that information to make instructional decisions (Wiliam, 2007). Research has shown that formative assessments in mathematics can positively impact student learning and achievement (Schoenfeld, 2015; Wiliam, 2003). Wiliam (2007) presented five critical strategies for implementing assessments for learning:

- clarifying and sharing learning intentions and criteria for success,
- engineering effective classroom discussions, questions, and learning tasks that elicit evidence of learning,
- providing feedback that moves learners forward,
- activating students as instructional resources for one another, and
- activating students as the owners of their own learning.

These strategies align with the practices already identified as elements of effective instruction and fall within the realm of ensuring student engagement in learning. They also emphasize the interconnectedness of many of the practices that can help students learn mathematics. Not intended to be evaluative, formative assessments gather information within the flow of instruction about what students are doing, thinking, and learning. They then use that evidence to inform decisions related to teaching and learning. Assessment is a vital component of instructional design and gives teachers and students the information needed to monitor and support learning (Black & Wiliam, 2010; Smith, Bill, & Hughes, 2008; Wiliam, Lee, Harrison, & Black, 2004).

Teaching mathematics can be challenging at any level, but there are specific challenges associated with teaching at the middle-grade level, where the research for this study occurred. Extensive research with middle-school-aged students, children between the ages of 10 and 15, has shown that students of this age have very different needs than young students and older adolescents (Grootenboer & Marshman, 2016) due to the extreme changes they are undergoing. Neuroscience has established that much of the behavior we associate with young adolescents is related to the changes in their developing brains (Feinstein, 2009). Effective pedagogy for students in this age range must consider their specific developmental stage and the associated changes they are undergoing. In addition to having specific social and emotional needs, students in this age group must also contend with the mathematical curriculum that moves from primarily concrete and number-based concepts to more abstract and complex content. An examination of effective instructional practices for teaching middle school mathematics must consider these specific factors. Additional resources related to the development of best practices for teaching middle school included *This We Believe, and Now We Must Act* from the National Middle School Association and *Turning Points 2000*, a report from the Carnegie Foundation. Any earnest attempt to explore effective instruction in middle school mathematics must incorporate the research on both mathematics instruction and human growth and development.

Technology and Mathematics Instruction

The use and integration of digital and electronic technology in teaching mathematics was once controversial but is an expectation in today's classrooms. Efforts to reform and improve mathematics teaching and learning have incorporated the use of technology, and current educational quality standards provide guidelines for the use of technology (ISTE, 2016; NCTM, 2000). In its publication, *Strategic Use of Technology in Teaching and Learning Mathematics* (2011), the NCTM clearly stated the dominant position concerning the instructional use of technology:

> It is essential that teachers and students have regular access to technologies that support and advance mathematical sense-making, reasoning, problem-solving, and communication. Effective teachers optimize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics. When teachers use technology strategically, they can provide greater access to mathematics for all students. (NCTM, 2011)

Technology is ubiquitous in modern living. Over the last several decades, middle school mathematics classrooms have seen an influx of technological enhancements. Some technologies, such as graphing calculators, computer algebra systems, dynamic geometry software, computer-based applications, handheld computation, data collection, and analysis devices, are content-specific (Prestagord, 2011). These enhancements can support students in problem-solving, reasoning, and exploring mathematical concepts. Other types of technology, such as interactive whiteboards, clickers, and Internet-based digital media, are content-neutral. These technologies can facilitate access to information and assist with communication and collaboration, supporting student reasoning and agency. Researchers have documented the promise of well-designed instructional use of technology to support learning and increase academic performance (Cheung, Cheung, & Slavin, 2006; Heid & Blume, 2008; Roschelle et al., 2010). It has been shown that when used strategically and appropriately, technology can enhance the teaching and learning of mathematics (Dick & Hollebrands, 2011).

Technology use is not the same thing as technology integration. Integration occurs when classroom teachers consistently use technology to introduce, reinforce, extend, enrich, assess, and remediate student mastery of curriculum. The integration of technology should focus on how and why technology can be used to extend exploration and student thinking to allow the construction of mathematical understandings. True technology integration in classrooms remains a challenge. Explorations of what technologies are being used and how they are being used can inform decisions that reinforce the real instructional value of such enhancements.

In "How People Learn," Bransford et al. (National Research Council, 2005) summarized the kinds of recommendations about how the interaction of technology use in the classroom creates an opportunity for teachers to think differently about the ways students are able to demonstrate what they know. As teachers use technology and begin to think differently about their teaching practices, they transform or begin to think differently about their role as teachers and, therefore, provide their students with different opportunities to demonstrate what they know. When teachers use technology in the classroom, each interaction affords the teacher another opportunity to interact with the student in a way that may not have been possible or available without the technology. Technology may also present the teacher with the opportunity to reflect on his or her practice or change teaching plans to accommodate the students in a way that may not have occurred previously. The teacher may begin to form different ideas about effective practice, effective use of technology, better student-to-teacher interactions, and possibly higher student achievement. Therefore, the technology may be a catalyst for additional student-to-teacher interactions.

Technology Use and Integration

Technology use in the classroom supports effective math teaching when it is used purposefully and integrated with instruction. One of the tools used to examine the integration of technology in the teaching and learning of mathematics is the Mathematics TPACK Standards developmental model (Niess et al., 2009). TPACK is a theory that attempts to identify the nature of knowledge required by teachers for technology integration into their teaching, while simultaneously addressing the complex nature of teacher knowledge (Koehler, Mishra, & Cain, 2013). The TPACK framework extends Shulman's (1986) idea of PCK. The TPACK framework goes further by emphasizing the kinds of knowledge that lie at the intersections between TPACK and three primary forms: PCK, TCK, and TPK.

The need to identify content-specific guidelines led to the creation of the Mathematics TPACK (M-TPACK) framework. As stakeholders in improving the quality of mathematics teaching and learning, the Association of Mathematics Teacher Educators (AMTE) collaborated with researchers and engaged in creating a set of standards to guide the professional practices of mathematics teachers and their use of technology. In creating standards specific to mathematics teaching and learning, consideration was given to the areas of intersection in TPACK. It was recognized that teachers need to be informed about various technologies and how they can be used to transform the manner in which the content is taught, and how their use changes the teaching and learning of specific mathematics (Mishra & Koehler, 2006).

The research leading to the creation of the M-TPACK model found that mathematics teachers progressed through a developmental process of five stages when learning to integrate a particular technology into their practice. They identified the five stages as:

1. *Recognizing* (knowledge), where teachers can use the technology and recognize the alignment of the technology with mathematics content, do not the technology in teaching and learning of mathematics.
2. *Accepting* (persuasion), where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics with appropriate technology.
3. *Adapting* (decision), where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with appropriate technology.
4. *Exploring* (implementation), where teachers actively integrate teaching and learning of mathematics with appropriate technology.
5. *Advancing* (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning mathematics with appropriate technology.

To refine the M-TPACK, the AMTE Technology Committee further identified four themes related to the development of teacher technology integration: curriculum and assessment, teaching, learning, and access.

The examination of teacher knowledge and the use of technology are not tied to just the TPACK framework. An alternate tool for analyzing technology integration and its impact on teaching and learning is the RAT framework (Hughes, 2005; Hughes, Thomas, & Scharber, 2006). The RAT framework focuses on how technology is used. This model uses three broad themes to examine the impact of technology use; instructional methods, student learning processes, and curriculum goals. As shown in Appendix A, Table A3 lists the various dimensions researchers have associated with the three themes.

To create a tailored tool for use in mathematics, Thomas and Edsen merged the teaching practices from NCTM's *Principles to action* (NCTM 2014) with the RAT framework (Thomas

& Edsen, 2016). Their study's stated goal was to identify the ways research-based best practices for teaching mathematics align with the technological tools being used in classrooms. The research leading to this framework specifically explored how elementary and middle school teachers select, use, and evaluate digital instructional materials. When technology use is for replacement, instructional methods, learning processes, and curricular goals are unchanged. Using an interactive whiteboard to present teacher-led lecture notes from a PowerPoint versus using a traditional whiteboard or chalkboard, for example, is a replacement-level technology integration. Amplification uses can increase efficiency and extend or enhance one or more dimensions. Using a calculator to check work after traditional paper and pencil algorithm practice is an example of amplification. Technology use that changes instructional practice, or curricular goals, or learning processes, is considered transformational. Allowing students to use a graphing calculator or software to model the relationship between graphical and symbolic representations of the rate of change could be an example of a transformative use of technology. Table A4 in Appendix A represents the work to align the NCTM effective teaching practices with the RAT technology implementation framework.

Flipped Learning

There are numerous names and definitions for the technology-enhanced blended instructional model known as flipped learning. Alvarez (2011) described flipped learning as a technique teachers use to record digital videos of direct instruction, providing an overview of what the students will learn, including the content, examples, and ending with a summary. This method allows for problem-solving, interactive lessons, and daily assignments all to take place within the classroom, providing more personalized time between students and teachers (Alvarez, 2011; Bergmann & Sams, 2012; Hamdan et al., 2013; Tenkely, 2012). Bergmann and Sams (2012) articulated that flipping a classroom is to deliberately redirect the teacher as the focus of the lesson, turning the attention and responsibility back toward the student. This redirection allows time for active learning strategies. Active learning, described by Michael (2006), is the process of engaging students in activities that require them to assess their progress, reflect upon new ideas, actively solve problems, and critically analyze new ideas. Through the time shift of direct instruction and the usage of technology, this instructional strategy has the characteristics of active learning. Students participate in constructing knowledge while working together as a group (Bergmann & Sams, 2012; November & Mull, 2012). Flipped learning is a type of instruction that researchers have associated with both active learning and student-centered instruction (Hamdan et al., 2013).

Characteristics of Flipped Learning

Flipped learning is an attempt to create more time for students applying new knowledge and active learning under the teacher (Bergmann & Sams, 2012; November & Mull, 2012). The primary characteristic of a flipped classroom is that homework and problem-solving aspects of learning are done at school while allowing the student to watch and listen to the direct instruction or lecture outside of class (Bergmann & Sams, 2012; Hamdan et al., 2013; Herreid & Schiller, 2013; November & Mull, 2012). Thus, the term flipped implies a shift in the way time is used between the consumption of knowledge and the interactive process of learning (Berrett, 2012).

Historical Perspective of Flipped Learning

Bergmann and Sams (2012), two chemistry teachers from Woodland Park, Colorado, are credited with initiating the current interest in flipped learning at the K-12 level. As teachers in a rural school district, they were faced with the challenge of needing to accommodate students who were missing class because of athletic programs and other extracurricular activities. They found the need to reteach concepts regularly because ofstudent absenteeism.

As a means of addressing the need, they began recording their lessons and posting videos for their students on YouTube. The use of this public forum meant that others could also view the videos, and they were surprised, as people contacted them from different parts of the world who were learning from their videos as well. The response to their efforts led Bergmann and Sams to promote this instructional strategy through various presentations, books, and lectures to share their ideas with others (Bergmann & Sams, 2012). One additional way they shared ideas was through creating a not-for-profit organization called the Flipped Learning Network. The network became a means to provide insightful skills and development strategies for teachers to use focused on maximizing the effectiveness of using flipped learning fortheir instruction (Hamdan et al., 2013). While Bergmann and Sams were not the first educators to use recorded videos in classes, they have become strong proponents of the use of this instructional strategy in secondary schools.

Salman Khan has been another seminal leader in the field of flipped learning. In 2004, he videotaped himself providing math lessons for his nephews in New Orleans to view (Khan, 2011). As with Bergmann and Sams, once Khan posted his tutorials online with YouTube, there was a positive response from viewers who were captivated by this new form of learning. Khan expanded this concept and eventually built Khan Academy, a vast nonprofit enterprise that now provides over 2000 different types of online tutorials in a wide range of subjects.

Technology, Entertainment, and Design (TED) is an organization promoting the combination of these three components in the collection of lectures of people with vast areas of expertise, creativity, and motivation (“Lessons worth sharing,” 2013). TED Talks began in 2006 with the posting of six videos, which set in motion an assembly of speakers becoming accessible for free, all over the world. The popularity of the TED videos led to a more specific education division called TED-Ed (“Lessons worth sharing,” 2013).

TED-Ed has included a component in which teachers can use a YouTube video for the flipped learning model and modify it according to the educator’s specifications. Features that can embed questions, comments, and other links with the final product can be customized to the teacher’s needs (McKernan, 2012; Tenkely, 2012). Such abilities to build lessons upon the creation of other videos, including discussion points and tracking of progress, add the dimension of the usage of videos for learning (McKernan, 2012; Tenkely, 2012).

Benefits of Flipped Learning

Educators have found several aspects of this method of teaching beneficial for students, one of which is the opportunity to learn from taped videos of instruction that allowed unlimited opportunities to watch the videos as often as needed (Hamdan et al., 2013). When a teacher presents new information in the classroom, it is offered one time in a setting prone to distraction and may move too quickly for some students to process what is being taught to them (Tyson, 2010).

Often, classrooms have disruptions from other students, school announcements, and issues with how fast or slow the teacher is talking (Finkel, 2012; Rhor, 2012). Instead of receiving one opportunity to comprehend the direct instruction, he or she can review and pause the video while taking notes, allowing the needed time to understand new concepts and new data. Ultimately, when students are allowed to intake direct instruction from lessons provided outside of the classroom, there is flexibility for students not only to choose how often they want to view the lessons but also where and when they want to see them (Tyson, 2010). Hamdan et al. (2013) noted that one benefit was the ability to prime students to remember key facts using the instructional video before a deeper level of engagement in class.

Bergmann and Sams (2012) noted that another useful advantage of having prerecorded videos available to students was to provide those who have frequent absences from class for various reasons the opportunity to still make progress by viewing instructional content at home. Herreid and Schiller (2013) noted a quality of the flipped model that appealed to teachers was that students who were being taken out of school could easily access the videos for their coursework lessons. Another benefit identified by teachers was that when they were absent, their digital recordings could be used by substitutes for instruction (Bergmann& Sams, 2012).

While recorded digital instruction is the instrument of change in flipped learning, it is what happens in the classroom that offers the most significant benefit of this instructional strategy (Bergmann & Sams, 2012). The flipped classroom becomes a more active learning, student-centered environment where teachers can spend more time providing individual assistance, engaging students in more collaborative problem-solving projects, and making formative assessments. This environment also provides increased time for facilitating the needs of students who require personalized attention (Bergmann &Sams, 2012; Fulton, 2012; Hamdan et al., 2013). Johnson(2013) noted in his research that technology is leveraged in the flipped classroom, allowing teachers more time to provide a learning experience in class that may include an in-depth exploration of ideas and essential feedback from daily activities. Gorman (2013) supported this idea by emphasizing that through detailed instructional videos viewed outside of class, students were encouraged to engage in related meaningful tasks at school.

Finkel (2012) noted that for students learning in a flipped classroom, there is a fundamental shift in where their authentic learning occurs. He emphasized that the desired conceptual learning requires active participation from students. Class time allows students to engage in cognitively demanding tasks while being guided by their teacher in a flipped classroom (Berrett, 2012). In the flipped classroom, students need to be taught how to stay focused, work collaboratively with peers, and be disciplined (Finkel, 2012; Fulton, 2012). In this learning environment, there is an expectation that students take ownership of their learning while assuming responsibility for their own learning outcomes (Bergmann & Sams, 2012; Hamdan et al., 2013).

It is now understood that flipped learning can be implemented in different formats and to various degrees. One example is the flipped-mastery classroom, where students are permitted to move at their own pace. Bergmann and Sams (2012) described this format as blending the concept of mastery learning with technology. The students who watch the videos and master the lessons' elements through the class activities are provided the next lesson and advance through the curriculum at their own pace. Bergmann and Sams (2012) noted that the flipped-mastery model permitted the teacher to provide needed supplemental assistance for individual students since there was more time for personalized education. Personalized learning is gaining popularity in many K-12 schools, and flipped learning provides a valuable tool for teachers in helping to manage the planning and student learning. Furthermore, by customizing the class time, this model potentially becomes the ultimate differentiated instructional environment. Johnson (2013), a practitioner, contended that he was able to spend quality time with a student who was struggling just as he could to assist a student in precalculus to extend thinking in ways that were not possible under the traditional approach of teaching.

Effectiveness of Flipped Learning

One particularly well-documented case in which flipped learning showed significant improvement in student performance occurred at Byron High School, near Rochester, Minnesota (Fulton, 2012). According to Fulton (2012), funding reductions associated with the 2009 recession resulted in the school district's decision not to purchase new math textbooks. Consequentially, the math teachers were asked to collaborate on ways to build their instruction and resources that would prove to be innovative, cost-effective, and promote academic growth among the students. Flipped math courses were implemented as a result of a collaboration between the technology department, educators of the district, and Byron High School (Fulton, 2012; Hamdan et al., 2013). Without the benefit of textbooks, the teachers relied on software sources that assisted them in creating their videos, which took the place of the textbook work, traditionally used as homework (Fulton, 2012).

According to data published by Fulton (2012) and Hamdan et al. (2013), the results of the Byron High School implementation of the flipped model showed considerable gains. In calculus, there was an average gain of 9.8% on assessments; precalculus rose 6.1%, accelerated algebra II showed improvement of 5.1% in the median assessment scores, and there were similar results in the other math course. According to Fulton's (2012) report, the most compelling evidence indicated that on Minnesota state standardized tests, Byron High School's level of math mastery went from 29.9% in 2006 up to 65.6% in 2010. As a result, the school embraced fully digitalized content in the classroom and maintained a flipped classroom learning environment. Consequently, nearly three-quarters of the students passed the state assessment in 2011 at 73.8% mastery, which was more than double the results from 2008.

In Michigan, Clintondale High School documented and promoted the flipped learning model's success when the entire campus switched to this mode of instruction in 2010 (Clintondale High School, 2012). Green (2012), the principal of Clintondale High School in Michigan, shared his school's passing results after the flipped learning model. He noted that according to the 2010 first-year-student campus data, failure rates in all core subjects decreased. In fact, in math, there was a 31% drop,science 22%, English language arts 33%, and 19% in social studies. The number of student discipline referrals was reduced in two years by 74%, suggesting that the flipped learning model may serve to increase student engagement and promote academic progress.

Effectiveness of Diverse Learners Using the Flipped Model

For English language learners (ELL), it is often a challenge for students to transfer their native language into English while simultaneously processing information being taught in a traditional teacher-directed lesson (Orosco & Klingner, 2010). According to Hamdan et al. (2013), many ELLs initially learn in the lower levels of Bloom's taxonomy, which is a basic comprehension of remembering and recognizing when focusing on direct instruction. As a result, when ELLs are provided direct instruction through digital media, they can pause, repeat, and review what is being said while moving at a pace that is beneficial to them (Hamdan et al., 2013).

Students with learning disabilities have also found support when using the flipped learning model (Bergmann & Sams, 2012; Bottge et al., 2014; Herron, 2013). Because teachers have been challenged to provide continual remediation and repetition for students during direct instruction, the flipped classroom avails the teacher more time to work with individual students in specific areas (Herron, 2013). Since the student can repeat the direct instruction as often as needed when viewing the videos outside of class, it has become a built-in support for meeting the students' individual education plan (Driscoll, 2012). Fulton (2012) also indicated that students who are working on the application of homework and interactive lessons in class would allow teachers to understand better the deficiencies of students who are having challenges and can better assist them.

While the flipped learning model holds promise for students with language and learning challenges, it also has great potential for advanced learners (Bergmann & Sams, 2012). Under Bergmann and Sams (2012) framework of the flipped learning model, they have included an extended level of its usage called the flipped-mastery model. This model is the logical extension of how far a flipped classroom can go if implemented effectively (Bergmann & Sams, 2012). Johnson (2013) described mastery learning as an approach to learning where students are allowed to achieve preset levels of competency, allowing them to move on to the next objective or lesson independently. Furthermore, Johnson (2013) indicated that while teachers have valued the concept of mastery learning, it is time-intensive to implement, consequentially discouraging teachers from incorporating mastery learning into their classes. He indicated it is for this reason the flipped learning model works so well for mastery learning. Under this form of learning, advanced students can view the videos, complete assignments, and provide evidence in the form of a project or activity that shows mastery of that particular concept (Bergmann & Sams, 2012). No longer does the advanced student need to be held back while the teacher has to reteach and slow the process for other students (Bergmann & Sams, 2012).

Effectiveness of Mathematic Students Using the Flipped Model

Innovative and meaningful educational technology has been considered a potentially useful tool to improve learning in math classes (Cheung & Slavin, 2011; U.S. Department of Education Office of Educational Technology, 2010). According to Green (2012), 31% fewer first-year students failed math at Clintondale High School in Clinton Township, Michigan, when instructed under the flipped learning model. Through the use of digital instruction from the Khan Academy, a middle school in the Los Altos district of California made significant gains in all math classes (Clemens, Fathers, & Izumi, 2013). The seventh-graders' results indicated that students who took the California standard exams went from 23% performing at or above proficient in 2010, to 41% in 2011. The same assessment also showed that the lowest performance levels decrease from 29% to 12%.

Perceptions of Flipped Learning

As with most new instructional strategies, there are many opinions and thoughts, and the flipped learning model is no exception (November & Mull, 2012). While it has shown much promise and energy from its supporters, some have shown caution and criticism toward the flipped learning model (Bergmann & Sams, 2012; Hamdan et al., 2013; November & Mull, 2012). Bergmann and Sams (2012) stressed that the flipped learning model is considered a dramatic shift from the traditional model since the Industrial Revolution. It should be examined and evaluated carefully by all stakeholders of education, including teachers, students, parents, and administrators. The flipped model does not merely change where lectures take place, but completely opens up the classroom in a very different and dynamic way, thus, potentially transforming the standard model of teacher-directed instruction (Tyson, 2010). In addition, Fulton (2012) noted that such dramatic changes in an educational system that has been firmly established for years might be met with caution and skepticism among teachers and administrators.

Teacher Perceptions

Bergmann and Sams (2012) believed that teachers have the most to consider when contemplating the flipped learning model's usage and implementation. For the educator, a new mindset is necessary when changing the face of a firmly established model of instruction that has been the standard for years (Fulton, 2012). Teacher-led instruction was developed generations ago, in which learning experiences were primarily linear, and the delivery was a strictly structured sequential approach (Wilmarth, 2010). Consequentially, modern teachers seek to flip their classroom instruction, presumed to break away from the norms of the past and create a multi-level, interactive, student-led learning environment where the teacher learns and facilitates alongside the students (Ertmer & Ottenbreit-Leftwich, 2010).

Fluker (2013) interviewed teachers who had taught in a flipped learning classroom. His article described how teachers found that flipping the class provided a better usage of time and resources. One instructor Fluker (2013) spoke with indicated that while preparing the videos in advance is time-consuming, it was worth it in the end because of the increased level of student engagement and participation. Rhor (2012) cited a teacher who stated that one benefit of flipping the classroom was that she had significantly more conversations and interactions with students. Under the flipped model, students were getting more individualized attention, and fewer are hiding or slipping through the cracks. Rhor (2012) reported that while there was enthusiasm from most teachers, the flipped learning model required giving up a certain amount of control in the classroom and was chaotic at times.

The Flipped Learning Network (2012) created a survey, along with Classroom Window, directed toward 450 teachers to ascertain teachers' perceptions about the use of this model in their classes. Among the responses, 66% of teachers indicated that state assessments improved after using the flipped model, 80% believed their students' attitudes were much better, and overall, most of the teachers found that teaching was much more satisfying under this model. Another notable result from these findings was that close to 9 of 10 teachers indicated an improvement in their job satisfaction.

In addition, the Speak Up National Research Project & Blackboard K-12 (2017) reported in a recent survey that of 56,346 teachers who responded in their research, 3,561 teachers have implemented a flipped classroom. Among this group, 48% viewed themselves as being more technologically advanced than their colleagues. Of these teachers, 60% thought their students were more motivated to learn in the flipped classroom, 45% believed that their students were taking more ownership of their education, 63% stated they were more organized, and 65% indicated they were creating more interactive lessons.

Student Perceptions

For students who participated in the flipped learning model, research suggested that students were positive about their overall experience (Hamdan et al., 2013). Johnson (2013), a math educator and researcher, analyzed his student responses to a quantitative survey related to the flipped learning model's perception. Some of the more notable themes that emerged from his study indicated that students feltmore connected to their teachers, and the time spent in class was more relaxing and engaging with other students. Also, the students noted that class time was not dull, and ultimately, they believed they were learning more than if in a traditional math class (Johnson, 2013).

Furthermore, Driscoll (2012) included a student and teacher survey in his research that gave further credence to the popular perceptions among students who had been instructed in a flipped environment. Among the more notable survey questions in his study directed toward students, the following stand out as indicators of positive results for flipped learning: 83% of students felt more active, with more opportunitiesfor authentic learning; nearly 79% found they had more opportunities to interact with their peers and teachers positively; 79% had more time to work at their own pace; and 80% thought that they had more accessibility to class resources and instruction (Driscoll, 2012).

Parent Perceptions

Shepard's (2013) interview with parents noted they believed the flipped model gave their children ownership of their education, and ithelped them to assist with their children's assignments. Parents were able to view content and information, often learning or reviewing concepts that empowered the parent to be educated as well (Alvarez, 2011; Baker, 2010). Bergmann and Sams (2012) described that during their parent conferences, parents conveyed how they learned the subject material with their students. The experience opened up a newfound dialogue between the students and their parents.

According to Bergmann and Sams (2012), the flipped learning model revealed a few surprises related to parental support. They indicated that parents learned how involved and in-depth teaching was when watching digital videos. An added appreciation was noted toward the teacher's role in their child's development. Consequentially, classrooms were made available for public viewing, which provided transparency to those who questioned what is actually being taught during instruction. According to Bergmann and Sams, posting their instructional videos online had dispelled some of the mystery and mistrust that kept parents at odds with their child's educational system, thus, creating a real understanding of the level and skills of learning taking place in school.

Some other benefits that parents found in having an instructional video available were that when their child was ill and could not attend school, they could still review the lesson from home (Bergmann & Sams, 2012; Fulton, 2012; Hamdan et al., 2013). Finally, Bergmann and Sams (2012) described a story of one teacher who was provided the unique opportunity to teach not only her young ELLs through the listening and reading of her materials, but the ELLs' families also were reaping the benefits of learning English as well.

In the Speak Up National Research Project and Blackboard K-12 (2017), 39,713 parents participated who answered questions over trends in online learning, which included blended and flipped classes. Of parents surveyed, 62% believed that the usage of online learning for their children would allow them to work at their own pace, and 59% thought online learning would provide their children the added benefit of being able to review materials as often as needed. Parents expressed a high interest, particularly in increasing opportunities for high school students to have online courses available. A third of those parents surveyed wanted schools to invest more in providing online classes.

Limitations and Critics of the Flipped Instruction Model

While there are recognized benefits to utilizing this instructional strategy, the flipped model has factors that may limit or compromise its success (Bergmann & Sams, 2012; Hamdan et al., 2013). One of the most pressing issues mentioned in the research was the accessibility for students, particularly in low-income areas, to view the digital videos in homes without computers or Internet access (Hamdan et al., 2013; Rhor, 2012). Bergmann and Sams (2012) discussed how they overcame that concern by first making sure the videos were available in different places and forms. They posted it online at both public sharing sites and the district server and provided opportunities for students to download them to a flash drive or load them on personal devices. If a student had no access to a computer, the teachers would burn copies on DVDs, as they learned that all of their students at least had a DVD player at home. November and Mull (2012) also suggested that schools should create outside opportunities for Internet access before and after school and provide a loaner program for students to use at home.

The second challenge of flipped learning related to teachers was the time invested in recording videos (Hamdan et al., 2013). In November and Mull's (2012) article, *Flipped Learning: Five Responses to Common Criticisms*, several solutions were offered to aid teachers who do not have the time to create all of the digital recordings. First, it is suggested that teachers share video recording roles so they can taketurns for each lesson. Working together as a team helped alleviate some of the time-consuming aspects of video recording and helped build a consensus among colleagues about the lesson's needs and goals. Also, November and Mull cautioned teachers not to obsess about making videos for every class, and instead, to start off with only one or two per week and gradually build up the video recordings as time allows.

Bergmann and Sams (2012) also suggested the option of utilizing other prepared videos available online through a variety of websites. They pointed out that for beginners, using other videos may be the best option in providing the extra time needed to prepare the classroom time activities. Gradually, teachers will be more confident and record their own instructional videos. Critics of the flipped model also argued that two aspects of this concept were contingent on doing homework and listening to lectures, which they considered to be the least effective way for students to learn (Hamdan et al., 2013).

Summary

According to research reviewed, mathematics instruction that is student-centered and inquiry-based provides the most significant opportunity for students to meet current learning objectives and proficiency goals. Mathematically proficient students exhibit not just procedural fluency but can use their knowledge to reason, think critically, and solve problems. Technology is one of the tools that can be used to help support student exploration and learning. However, teachers are the most critical agents in reform practices and decision making in the classroom (Marzano, 2012). How they implement technology, structure tasks, and interact with students are the key elements in determining student outcomes. The flipped instruction model can be used to restructure class time and to provide students with a sense of agency in their learning. More research is needed on the best ways to integrate technology with effective teacher practice and on how specific technologies impact teaching and learning.

CHAPTER 3: METHODOLOGY

Introduction

The research questions for this study focused on three distinct topics.

1. How does the use of the flipped learning instruction model affect teaching and learning in middle-grade classrooms?
2. How does the use of flipped learning instruction affect student engagement and motivation?
3. In what ways, if any, does flipped learning impact the "gaps" in student achievement?

The research study design and methodology were created to answer these questions.

Design

Using case study methods, this study involved conducting research in a middle school with multi-age seventh- and eighth-grade mathematics classrooms. Consistent with the case study methodology, this study examined and described events that took place at a specific time in a specific school. There were no researcher-applied interventions; instead, the researcher reviewed the unfolding of a school-initiated mathematics instructional strategy. Data collection took place while the event was taking place. The desired outcome was to develop some understanding of the classrooms where flipped instruction was used. Based on these factors, a case study design was deemed most appropriate because of its ability to focus on gaining an in-depth understanding of complex social phenomena at a specific time (Yin, 2012)

Following the research questions, one goal of the study was to examine the teacher's role in the flipped classroom compared to a traditional classroom. Another goal was to establish common ideas and impressions that emerged during the flipped learning instructional model's implementation as related to student engagement, attitudes, performance, and the perceived effectiveness of thismodel. To establish a solid understanding of the phenomenon of learning through the flipped model, a variety of data were collected. Utilizing current research practices and data analysis tools, the study's primary goal was to understand how flipped learning was implemented in this setting and examine some of its impact on teaching and learning.

The Case

The setting for this study was a public magnet middle school in an urban North Carolina city. The school is a certified Montessori site and Magnet School of Excellence. This magnet's focus is on developmentally appropriate learning experiences in a student-centered environment utilizing Montessori methods. As part of the local public-school system, students must apply to the school, and most are admitted from Montessori magnet elementary schools. The middle school was founded in 2010 to meet parent demand for an extension of the Montessori-based learning environment, which existed at the elementary level. In this setting, as is the case with most Montessori programs, design decisions and students groupings are based on student developmental levels. The structure of traditional middle schools does not match the Montessori developmental ranges of 9-12 years and 12-15 years. Because of this, 6th grade students are in single grade groupings while 7th and 8th-grade students are in multi-grade groupings.

Admissions decisions for sixth grade were made using a lottery. Students in the seventh and eighth grades remained enrolled unless parents chose alternate placement. Students in sixth grade were placed on two teacher teams called communities, where they received instruction in the core subjects of mathematics, science, and humanities. Students in seventh and eighth grade were placed in one of four multi-age communities, where they remained for two years and received differentiated instruction in humanities and mathematics. Science instruction was grouped heterogeneously, and all community students were taught the same curriculum. The curriculum alternated each year so that after two years, all community students had received instruction in the state science curriculum for both seventh and eighth grade. Elective choices included typical courses such as health, physical education, band, and art, along with more atypical options aligned with Montessori education such as yoga and Latin. The district's demographic distribution was 33% Hispanic or Latino, 42% black or African American, 19% white, and 6% multiracial or other. The demographics for this school were 25% Hispanic or Latino, 25% black or African American, 43% white, and 7% multiracial or other (NCDPI, 2019).

Montessori programs differ from traditional schools in some very fundamental ways. Aside from the multi-age grouping, one of the other distinctions is the student-centered focus. Little to no emphasis is placed on academic competitiveness. There are no Honor Rolls at this school. Instead students are encouraged to be enthusiastic learners and explore their own interests. Teachers spent more time working with students in small groups and one-on-one than in whole group activities. Students are often given choice in the assignments they complete, their use of class time, and the amount of time they are allowed to complete their work. Student core instructional time is chunked in 110-minute blocks. During one of the blocks students study humanities, and in the other they study math and science. The ridged structure of classwork and homework does not exist, with required homework being a rare occurrence. Students are encouraged to pursue their individual interests, a practice based on Montessori's belief in children's inner hunger to learn. The physical arrangement of the classrooms, known as the "prepared environment" was consistent with Montessori design. A large carpeted area in the room was used for lessons and activities, centers with manipulatives were available for students to use at their will, student desks were frequently rearranged to accommodate self-selected workgroups.

The school has met expected growth academically since its inception. However, within the school, discrepancies exist between the performance of majority and minority students. An exceptionally large "gap" exists in mathematics performance between white and non-white students. Thus, the case focused on African American students making the transition from traditional mathematics instruction in sixth grade to the flipped instruction mode in the seventh grade to examine in more detail the issue identified in research question three about achievement gaps. There was also a large gap between white and Hispanic students, which was considered and investigated but not to the same level of detail as the African American students. Each of the seventh- and eighth-grade teachers in the above-described public middle school instructs two standard single-grade science classes and two classes of mixed-level mathematics. Responsive to the multi-age environment typical for most Montessori classrooms and students' varied mathematics achievement; teachers provided instruction for three state-designated curricula: standard seventh-grade mathematics, advanced seventh-grade mathematics, and standard eighth-grade mathematics. Students taking high-school-level courses (i.e., Math 1 or Math 2) were taught by a separate teacher outside of the community. Thus, the average mathematics class size was 16 students. "Work cycles," the instructional sessions, lasted 110 minutes. All communities had two work cycles per day. There was a humanities work cycle and a math-science work cycle. The math-science work cycle was divided between mathematics instruction, science instruction, and Montessori activities.

Sample

The case initially intended to focus on seventh-grade students in the four multi-grade communities because it was their first year experiencing flipped instruction. Unfortunately, one community had to be excluded from the study because it did not have a full-time mathematics teacher during the data collection period. This exclusion left a total population of 76 students in the seventh grade across three mathematics teachers. Twelve students from these three communities were taking advanced math one (four from community A, three from community B, and five from community C) because this class was taught off community by a different teacher. These students also were excluded from the study. The exclusion of these students left 64 students in the study, 23 of whom were African American and 19 of whom were Hispanic. Among these 64, 8 were identified for math enrichment and received additional twice-weekly direct instruction from the advanced mathematics teacher.

Teachers

Three teachers and their students provided the data for this study. All the teachers have taught at the study site for at least three years. Each was classified as "highly qualified" to teach middle-grade mathematics based on the state of North Carolina standards. They also were all trained and certified in middle-grade Montessori education through the Cincinnati Montessori Secondary Teacher Education Program of Xavier University. Teachers planned collaboratively and used common instructional resources and assessments. Formal planning meetings occurred at least once per week for 90 minutes. Responsibility for creating the instructional videos used in their flipped classrooms was shared. Most videos featured the same teacher, though all three were involved in the planning and content selection. During this study, the group was in their second year of working together to teach the seventh-grade math curriculum using the flipped model.

Students

Table 1 provides data on the frequencies of students by community, sex, and ethnicity.

Although efforts were made to create demographically similar communities, some differences can be identified from the table. Differences in the numbers of seventh-grade students per community are directly related to the number of eighth-grade students in the community, as each grouping consists of approximately 50 students. The male to female ratio in this grade level was also unbalanced. Community B, which had more than double the number of males as females, had the most significant imbalance. All the student participants completed sixth grade at the same school and experienced traditional classroom instruction in mathematics.

Table 1

Number of Students in Study by Community, Sex, and Ethnicity

	Community A	Community B	Community C	Totals
Total number of students	16	24	24	64
Number of male/female students	8/8	17/8	11/12	36/28
Number of White students	4	6	12	22
Number of African American students	6	8	9	23
Number of Hispanic students	6	10	3	19

Among the African American students, distribution across communities was very similar; six students were from community A, eight students from community B, and nine students from community C. Community C had the greatest number of white students and the fewest Hispanic students. This group had proportions similar to the larger seventh-grade group, 7 of the participants were female (35%), and 13 were male (65%). Nine of the 20 students performed below grade level on sixth-grade end of year standardized math tests, which means 11 were at or above grade level. The study group's grade-level proficiency rate was 55%, which was significantly higher than the school-wide proficiency rate for African American students (37.5%) but substantially lower than the proficiency rate for white students (95%). While these differences are of some interest, two chi-square tests for ethnicity by the community and sixth-grade end of year results by level revealed non-significant differences ($p = 0.154$ and $p = 0.115$).

Instrumentation

Data collection crosswalk. Various data were collected during the second half of the fall 2019 semester to address the three distinct research questions. In striving to answer each research question, multiple data sources were used, and some data were used for various questions. Table 2 illustrates the types of data collected and the question to which it was related.

Table 2

Data Collection Crosswalk

Research Questions Around Flipped Instruction	Teacher Focus Group & Interviews	Student Surveys & Focus Groups	Observations /Materials Review	EOG & Case 21 Assessments	Teacher-made Assessments
1. Effect on teaching & learning	X	X	X	X	X
2. Student engagement & motivation	X	X	X		
3. Changes in the achievement gap		X		X	X

TEACHER FOCUS GROUP AND INTERVIEWS

A specific focus group and follow-up interviews with the teachers were conducted during October and November 2019. A focus group using the formal protocol (see Appendix B) was held during a scheduled department meeting and had a duration of approximately 45 minutes. All three teachers participated at the same time. Additional individual informal follow-up interviews were conducted with each teacher during the observation period. The informal interviews were documented in the field notes for the observations and were intended to clarify observed activities and lessons. The number of informal interviews varied: three with community A teacher, two with community B teacher, and five with community C teacher.

Student Surveys and Focus Groups

At the start of the school year, all seventh-grade students participated in a reflective writing exercise, exploring their perceptions of the sixth-grade mathematics experience. The selection of student participants for the focus groups was partially based upon those written reflections, in addition to standardized test performance data and recommendations from sixth-grade teachers. All 23 African American students were invited to participate in focus groups of 3 to 4 students to explore more in-depth questions around the flipped instruction. Three parents declined permission for their students to participate in these focus groups, so 20 of the 23 African American students were interviewed. A brief survey was given to focus group students at the beginning of the observation phase to assess their attitudes about flipped methodologies. Focus group interviews, with three to four students, took place over two weeks in November. The interview sessions lasted between 30 and 40 minutes. The student survey and student focus group protocols are attached in Appendices B and C, respectively.

Observations and Materials Review

Additional data collection included observations of classroom activities and the online instructional videos aligned with the lessons. Each of the three classrooms was observed twice per week during a four-week observation period. Observations occurred at the same time each session and lasted for 45 minutes, conforming to scheduled instructional math times in the classrooms. Table 3 outlines the observation schedule.

Table 3

Classroom Observation Schedule

Community	Observation Days	Observation Times
A	Monday, Wednesday	12:30-1:15 pm
B	Tuesday, Thursday	12:30-1:15 pm
C	Tuesday, Thursday	1:20-2:05 pm

During each observation, field notes were taken, documenting both the teacher's and the students' actions. All classrooms were multi-grade and included both seventh- and eighth-grade students. However, for this study's purpose, only the efforts of seventh-grade students and teacher interactions with those students were documented.

Teachers used common lesson plans and shared tasks, assignments, and assessments. Teacher resources were examined and used in conjunction with the observation data to assess technology use in these classrooms. The observations took place in November and December. Both the TPACK framework (Mishra & Koehler, 2006) and RAT framework (Hughes, 2005; Hughes et al., 2006) were utilized to assess the level of technology integration achieved as a means of exploring the impact of flipping instruction.

End-of-Grade (EOG) and Case 21 Achievement Data

In this study, two different types of standardized assessments, the EOG test and the Case 21, were used to examine student performance following flipped instruction. These same data were also used to examine variation by subgroup. Students in North Carolina public schools are administered state-provided standardized assessments at the end of each school year. These EOG tests assess academic growth based on a year of instruction and determine readiness for grade-level instruction. Case 21 assessments are standardized formative assessments given at the beginning of the year (BOY) and the end of the first semester. State and district curriculum and pacing guides are used to create these assessments. Because the Case 21 are formative, data from these assessments are used to plan and drive instruction.

For the EOG assessments, the state reported results as a scale score and as an achievement level. Scale scores and achievement levels were recalibrated for mathematics tests in 2019. Below are the different achievement levels with descriptors as provided by the North Carolina Department of Public Instruction:

- Not proficient: Students who are not proficient demonstrate an inconsistent understanding of grade-level content standards and will need support.

- Level 3: Students at level 3 demonstrate a sufficient understanding of grade-level content standards though some support may be needed to engage with content at the next grade/course.
- Level 4: Students at level 4 demonstrate a thorough understanding of grade-level content standards and are on track for career and college.
- Level 5: Students at level 5 demonstrate a comprehensive understanding of grade-level content standards, are on track for career and college, and are prepared for advanced content at the grade/course. (NCDPI, 2019)

Based on the North Carolina State Standards, the analysis in the North Carolina Testing Program Technical Report (2015) evaluated the validity of the test utilizing Cronbach's alpha at 0.93.

The other assessment, Case 21, was administered at the beginning of the year (BOY) and middle of the year (MOY). These assessments were created by the testing firm TE21, Inc. According to TE21, their assessments are valid and reliable. They are based on the North Carolina standard course of study and use sufficient numbers of questions and allow adequate time for students to take the tests. These assessments typically reported above 90% reliability regarding how well students were likely to perform on state tests. Case 21 tests measure what is expected to be covered in the curriculum during the time preceding the tests. This information is utilized in assessment creation and scoring to ensure their validity. The Case benchmarks are aligned to a school district's curriculum and pacing (TE21, 2019).

Each of the Case 21 assessments contains 35 test items. Score reports include percent correct and projected achievement level on the state EOG test. A percent correct score of less than 40% was associated with performance below grade level (not proficient). A percent correct score of 40% to 50% was associated with low grade-level performance (level 3), and a percent correct score of 50% to 60% was related to high grade-level performance (level 4). Above grade-level performance was determined by a percent correct score above 70% (level 5; TE21, 2019).

Teacher-made Assessment Data

To help investigate the research question related to student performance, the researcher had hoped to include teacher-made assessment data. However, the teacher-made assessments were given and reviewed by the researcher, and the format, number, and types of assessments varied from teacher to teacher. For reliability and validity, the analysis of this data was, therefore, excluded from the study.

CHAPTER 4: ANALYSIS

To summarize the findings, each section presents the data by research question from the various sources gathered. As a reminder, this investigation focused on three research questions:

1. How does the use of the flipped learning instruction model affect teaching and learning in a middle-grade classroom?
2. How does the use of flipped learning instruction affect student engagement and motivation?
3. In what ways, if any, does flipped learning impact the "gaps" in student achievement?

Question 1: How Flipped Learning Affected Teaching and Learning

The first research question was: How does the flipped learning instruction model affect teaching and learning in a middle-grade classroom? Due to this question's complexity, three sub-questions were created in an attempt to address its multiple facets: (a) What happened in the classroom when utilizing flipped instruction? (b) What were students doing during class time? and (c) Did mathematics achievement improve? Teacher focus groups and interviews, class materials and observations, students' grades, and standardized test scores were the data used to answer these specific questions.

What happened in the classroom? In total, there were 24 separate observations. Each teacher was observed eight times. During some observations, more than one activity occurred during the class period, which explains the total frequency being greater than 24.

For data collection, field notes were collected and then coded for observed activities. These observed activities were subsequently grouped into six categories:

- the teacher providing direct instruction,
- teacher working with an individual student or small group,
- student using computer to view direct instruction video and take notes,
- student working independently on assignments without computer,
- student working independently and using computer on technology-based task, and
- students working collaboratively on a task.

Table 4 summarizes the data collected for interactions with seventh-grade students. Given the challenge of observing large numbers of student classroom interactions and the third research question, which focuses on changes in the achievement gap, the researcher focused on the 20 African American seventh-grade students in the three communities exclusively; the data in Table 2 reflect those circumstances.

Table 4

Classroom Observations Data

Activity (n = 8 observations for each teacher)	Direct instruction by teacher	Teacher with an individual or small group	Students viewing lessons and taking notes	Students working independently; no computer	Students using computer-based programs	Students working collaboratively, no computers
Teacher A	1	1	2	4	1	1
Teacher B	3	2	2	4	0	3
Teacher C	2	4	5	3	2	3
Frequency	6	7	9	11	3	7

In general, teachers in these flipped classrooms spent a relatively small portion of class time providing direct instruction. The in-class direct instruction offered by teachers consisted of mini-lessons and assignment reviews. These activities lasted between 7 and 15 minutes. The teachers primarily spent time either working with individual students and small groups or monitoring student activities. The teacher interactions with the eighth-grade students present in the classroom during the 45-minute observations were not captured in the data.

A review of teacher lesson plans revealed a large amount of advance work, which allowed for a high degree of student independence during class time. Students accessed the teacher-made videos via Google Classroom. The prerecorded video lessons were accompanied by guided notes and included guided practice embedded by the software program Edpuzzle, which was utilized in the making of the videos. Each student was provided with a "work plan" for a two-week period, which outlined the tasks and assignments to be completed. Each student was provided a work folder at the beginning of the two-week cycle that included the work plan and copies of lesson guided notes, guided practice assignments, and all the physical documents needed for the two-week cycle. Teachers also prepared "controls" or answer keys kept in a designated location within the classroom, which allowed students to check their work as they completed tasks. In addition, hands-on activities called "shelf work" were prepared and set up in the classrooms for student use during class time.

What Did Students Do

Developing student independence and the ability to complete academic tasks independently is one of the critical components of Montessori education. The data collected supported the use of this strategy during the flipped instruction. Table 5 shows the frequency of observed activities.

Table 5

Student Activities During Observations

Activity (n = 8 observations for each classroom)	Whole group lesson; direct instruction by the teacher	Individual or small group work with the teacher	Viewing pre-recorded lesson and taking notes	Working independently; no computer	Using computer-based programs	Working collaboratively, no computers	Off task
Classroom A	1	1	2	4	1	1	1
Classroom B	3	2	2	4	0	3	
Classroom C	2	4	5	3	2	3	1
Totals	6	7	9	11	3	7	2

Figure 1 displays the percentages of the students' activities observed. Students were engaged in independent activities, with or without the computer, more often than any other activity. The viewing of the instructional videos and notetaking was encouraged and permitted during class time. Students were observed working independently with headphones and guided notes using their class time to receive direct instruction. Lesson resources included tasks and other opportunities for independent practice, which was also frequently observed. Some of the opportunities observed were paper and pencil, and some were using the Internet-based application, Desmos.

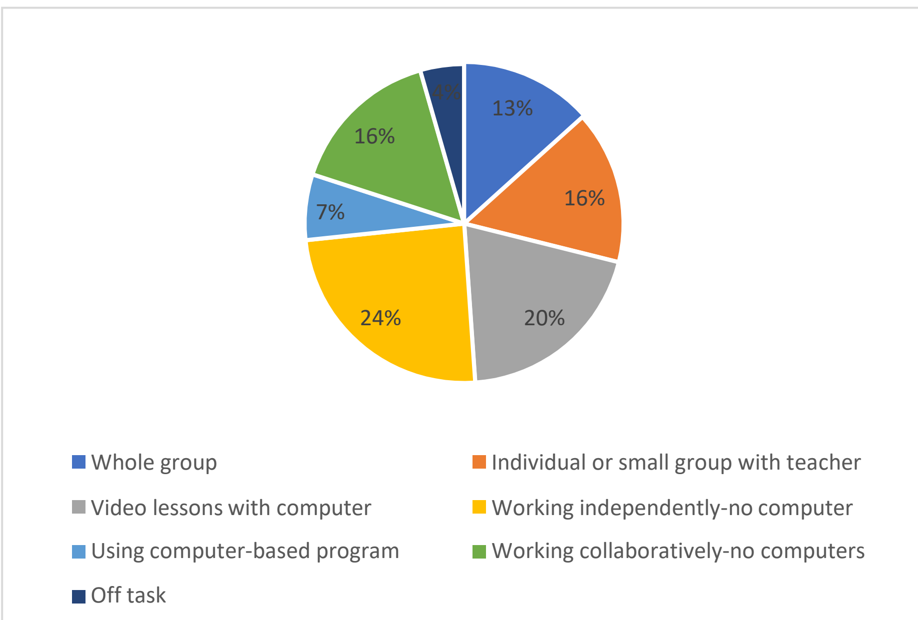


Figure 1. Percent of student activities observed.

In a Montessori classroom, "shelf work" consists of practice activities designed to build student understanding through manipulatives. The Montessori philosophy promotes the use of games, puzzles, and other hand activities as valuable tools to enhance learning. Student use of shelf work was observed as both independent and collaborative activities. Shelf work is among the choice activities on student work plans, which include both required and choice or optional activities. This strategy allows for differentiation without creating separate work plans for students of different abilities (Lilliard, 1996).

Students' Perceptions of How Flipped Instruction Affected Their Learning

Students participated in focus group interviews facilitated by the researcher. The focus group protocol is in Appendix C. Focus groups consisted of either three or four students and took place during the school day, in a conference room. Interviews were recorded and later transcribed and coded. Analysis of the data yielded several themes related to the ways that the flipped instruction affected their learning.

Use of instructional videos. When asked about the use of instructional videos in math class, respondents indicated that the videos allowed them greater flexibility and a measure of self-regulation, which they all viewed positively. Quotes from students around this topic include:

> "With the videos, you can work at your own pace."
>
> "I like switching between things, so on a video lesson, I can press pause and move on and do something else, then come back later. You can't do that with a regular lesson."
>
> "I watch the videos in class, and then I am able to do the practice, but if I can't do it, then I just watch it at home."
>
> "With video lessons, you can do them at home or at any time versus just when the teacher is giving the lesson."

Ability to repeat the lesson. Students also indicated that another positive and motivating factor of flipped instruction was the ability to repeat the lesson as needed by re-watching the videos and better relationships with their teachers. The following student quotes supported this:

> "This year, we have the video lessons, so if you get stuck, you can just watch the video again."
>
> "The video lesson is always there for you, so you can always go back."
>
> " It is easy to finish a video lesson at home or watch it again if you need help."

"It's like having your teacher there with you. You have a one on one lesson with your teacher."

Improved ability to focus. Another benefit that students saw to flipped instruction was improved ability to focus. One student observed, "I feel like when we were all sitting around listening to the teacher, it is a lot easier to zone out." Another student commented, "I feel like it's a lot better when you are listening by yourself rather than trying to listen to the teacher talk to the whole class."

Causing less anxiety. Another theme that emerged in student focus group interviews was that flipped instruction classrooms caused less anxiety than traditional settings. Students talked about the flipped instruction being easier with less stress. Comments included:

"I like having the video lesson. It makes it not as stressful."

"My teacher makes all the videos. If there is something in the video that you don't understand, you can just go ask them. No worries."

"Feels like it is easier (than last year)."

"I think this is easier. You have enough time to do the work."

"This is a lot less stressful."

Did Mathematics Achievement Improve?

For this study, comparisons of standardized test scores were used to assess mathematics achievement. State standardized EOG test scores from sixth grade were utilized to investigate the extent to which students in the communities were equivalent. A comparison of scores from the seventh-grade standardized BOY assessment to scores from the standardized MOY assessment assessed academic growth. This comparison also helps illuminate the extent to which achievement may have improved in the flipped instruction classrooms.

To review the different achievement levels of students in the study upon entering seventh grade and to explore the equivalence of communities in terms of achievement, Table 6 presents sixth-grade EOG results by the community. As confirmed by a chi-square test and as shown in Table 6, there were no significant differences in students' distribution based on achievement. More than half of the students who were non-proficient at the end of sixth grade were in community B. The rest were distributed relatively equally between communities A and C. Community C had more students firmly at or above grade level than below. This dynamic was the reverse of conditions in the other two communities.

Table 6

Frequency of EOG Achievement Levels by Community

	Not Proficient	Level 3 Sufficient Understanding	Level 4 Thorough Understanding	Level 5 Comprehensive Understanding
Community A	9	2	4	1
Community B	13	0	9	2
Community C	5	4	11	4
Totals	27	6	24	7

Notes. Chi-square = 10.24, $p = .115$.

To investigate the extent to which achievement improved in the flipped classroom, students' BOY percent correct scores were compared with their MOY percent correct scores. Table 7 provides means and standard deviations for the 64 students in the 3 communities. As shown in the table, the mean score for the MOY test, given following flipped instruction, was higher than the mean score of the BOY; however, these differences were not significant.

Table 7

BOY Compared to MOY Paired Samples Statistics

		M	*N*	*SD*	Paired *t*
Pair 1	BOY	47.69	64	21.949	
	MOY	50.06	64	23.443	−1.636 ($p = 0.107$)

As overall mean differences were not significant between BOY and MOY scores, the researcher examined if there might be differences among EOG levels regarding the number of students reaching proficiency. Table 8 provides achievement data for the BOY and MOY assessments, using the same levels used by the EOG assessment. As can be seen, the number of proficient students increased after flipped instruction. Two more students were able to demonstrate proficiency on the MOY assessment than on the EOG. However, the number of students in the upper two levels decreased. The most significant change occurred at level 4, where eight students improved performance, but five students performed at a lower achievement level. Examination of the scale scores shows a broader range of scores in the level 4 achievement level. The data suggest that mobility within this level is related to how close EOG and BOY scores were to the maximum and minimum scores for the level.

Table 8

Frequency of Achievement Level BOY to MOY Data

	EOG	BOY	MOY
EOG not proficient	27	26	25
EOG proficient	37	38	39
Level 3	6	8	12
Level 4	24	22	12
Level 5	7	8	15

To investigate differences among communities, further data analysis was conducted. All three communities showed an increase in the number of students performing at the highest level when comparing EOG and BOY to MOY. Two of the three communities also showed an increase in the number of students testing as proficient when comparing EOG and BOY to MOY. Community C had one student who previously tested as proficient who tested as non-proficient on the MOY assessment.

Table 9

Frequency of Achievement Level BOY to MOY Data by Community (n = 64)

Achievement Level	Community A			Community B			Community C		
	EOG	BOY	MOY	EOG	BOY	MOY	EOG	BOY	MOY
Non-proficient	9	11	7	13	12	12	5	5	6
Proficient total	7	5	9	12	13	13	18	18	17
Level 3	2	2	4	0	1	5	4	4	3
Level 4	4	2	3	10	9	2	10	9	7
Level 5	1	1	2	2	3	6	4	5	7

Further examining individual students, comparing the BOY score to the MOY score showed that 11 students experienced a decrease in the percent of questions answered correctly, 1 had unchanged scores, and 8 experienced an increase in score. Of the students whose scores on the assessments increased, four were non-proficient on the EOG and had previously scored less than 25% correct. This group, which had the lowest scores overall, was able to demonstrate some improvement in performance. The remaining students whose performance improved all began with at least 65% correct, and performance at this level was deemed securely proficient. The three students with the highest EOG scale scores also increased their percent correct score from the BOY to the MOY. The remaining students, who saw no improvement or a decrease in scores, ranged from struggling learners to previously high performing ones.

Question 2: How Does the Use of Flipped Learning Instruction Affect Student Engagement and Motivation?

There are myriad different definitions and elements of motivation and engagement. As used here, student engagement was defined as student interest and involvement in learning and the value associated with learning the content. In this study, motivation was defined as the inclination to do certain things and avoid doing others (Wang, Fredricks, Ye, Hofkens, & Linn, 2016). Student engagement and motivation have reportedly improved with flipped instruction (Bergmann & Sams, 2012; Fulton, 2012; Hamdan et al., 2013). Student surveys, classroom observations, and student focus groups were used to assess the effects of flipped instruction on students' engagement and motivation in math class. The data gathered supported improved motivation and engagement with flipped instruction.

Engagement

Student activities during classroom observations was one of the measures used to determine engagement. Time on task, utilized as an indicator of engagement, was consistently high during all observations. Whether students were working independently, in small groups, or whole group settings, only two instances were observed, where students were not engaged in working on math lessons or assignments. Students stated in the focus group interviews that they were invested in watching the videos and completing the assignments. Several students noted that they watched some videos multiple times to make sure they understood the content.

Motivation

Viewership of the videos and completion of work were used as indicators of motivation. Students were questioned about video viewing habits in both the survey and the focus groups. An initial question was if access might be a barrier to the flipped classroom. Mid-semester survey data indicated that all students had access to technology that let them view the videos outside of the classroom. As shown in Table 10, which summarizes some of the survey question data collected mid-semester before observations began, students watched the videos and completed the "guided notes" associated with the videos consistently.

Also, all students reported watching at least half the videos from the student survey responses at mid-semester. More specifically, 35% (n = 7) of students reported watching all 10 of the videos, 20% (n = 4) indicated they had watched 9, and 15% (n = 3) 8, 15% (n = 3) 7, 10% (n = 2) 6, and 5% (n = 1) 5 videos. During student focus group interviews, several students who reported not having watched all the videos indicated that they did not watch because they were exempted from doing so by the teacher or that they were able to complete the notes and assignments without viewing the video.

Mid-semester survey data also indicated that students did not necessarily think that watching videos outside of class made class time more engaging. In many flipped environments, the expectation is for viewing instructional videos to occur outside of the classroom. In this setting, students were allowed and encouraged to use class time to view videos. As per classroom observation data, instructional video viewing was the most common activity. Utilizing class time for viewing videos could explain student reports of video usage not making class time more engaging.

Table 10

Beginning of Observation Phase Student Survey Results = Frequencies (Percent)

	Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
I prefer video lessons to traditional classroom lessons			6 (30%)	7 (35%)	7 (35%)
I learn better with videos than I do from traditional classroom lectures.			6 (30%)	12 (60%)	2 (10%)
Watching videos outside of class makes class time more engaging		2 (10%)	9 (45%)	9 (45%)	
I have access to technology that lets me view the videos outside of school.					20 (100%)

Based on survey and focus group data, most students preferred video lessons compared to traditional classroom instruction. Students reported that they learned better from the videos than from traditional instruction. This environment also seemed to impact student self-efficacy around mathematics. Studies have demonstrated (Warshauer, 2014, 2015) that changing students' beliefs from a focus on the ability to a focus on effort increased their engagement in mathematics learning. This shift in focus, in turn, improved mathematics outcomes. Children in these studies believed that their efforts to learn made them "smarter" and showed greater persistence in mathematics learning. Among students in this study at midsemester, 75% reported that they were "good" at mathematics and felt somewhat successful in the flipped math classroom.

Question 3: How Flipped Instruction Impacted "Gaps" in Student Achievement?

The performance differences between white students and students of color have been well documented. As equity issues have gained importance in educational institutions, closing the opportunity and achievement gaps has become a focus of effort and attention. Flipped learning has been one of the instructional strategies reported to impact positively closing the achievement gap in mathematics (Corey & Bower, 2005; Martin, 2012). The third research question in this study sought to assess how the version of flipped instruction used at the middle school in this study might have affected these achievement gaps.

Overall performance data for all 64 study students were reported earlier in this chapter for research question 1. For research question 3, performance data were compared between subgroups that historically showed gaps in achievement. To assess the impact flipped instruction had on the achievement gap, performance means were calculated on the same standardized tests used earlier. Scores were reported as percent correct. Score means for white students were compared to those of African American and Hispanic students. Table 11 provides a summary of achievement test scores by ethnicity for the students in the sample.

The average scores for white students exceeded those for African Americans or Hispanics across both BOY and MOY assessments. Consistent with the overall findings for question 1, a paired *t*-test comparison showed no significant difference for each of the groups from BOY to MOY.

Table 11

Paired t-*test for Differences in Performance BOY" to MOY by Ethnicity*

Ethnicity	Number of Students	BOY Mean (*SD*)	MOY Mean (*SD*)	*t*-test (*p* level)
White	22	66.27 (8.464)	70.18 (15.92)	-1.61 (.123)
African American	23	42.43 (22.35)	40.83 (21.93)	0.873 (.392)
Hispanic	19	32.53 (17.09)	37.95 (16.77)	-1.709 (.105)

While the data do not support any significant changes in achievement for the subgroups from the BOY to the MOY, an analysis of variance was performed to test the presence or absence of significant achievement gaps among the three groups. Table 12 shows that there were significant gaps among groups for both the BOY and MOY assessments. Both Scheffe and Bonferroni, multiple comparison procedures, confirmed that the significant differences were between white students and the two other subgroups (i.e., African American and Hispanic students).

Table 12

Presence of Achievement Gaps among Groups for BOY and MOY Assessments

Ethnicity	Number of Students	BOY Means (*SD*)	ANOVA Results	MOY Means (*SD*)	ANOVA Results
White	22	66.27 (8.464)		70.18 (15.92)	
African American	23	42.43 (22.35)		40.83 (21.93)	
Hispanic	19	32.53 (17.09)		37.95 (16.77)	
	64	47.69 (21.95)	$F = 21.654$ ($p = .000$)	50.06 (23.44)	$F = 19.867$ ($p = .000$)

Another statistical measure, effect size, was calculated to determine if there was a change in the gaps from BOY to MOY. As shown in Table 13, a comparison of effect size for the BOY assessment to effect size for the MOY assessment saw an increase for African American and Hispanic students. It appears that, in this instance, the flipped learning model did positively improve achievement but not the racial achievement gaps.

Table 13

Effect Size Differences BOY to MOY

Ethnicity	Number of Students	BOY Means (*SD*)	Effect Size Differences	MOY Means (*SD*)	Effect Size Differences
White	22	66.27 (8.464)		70.18 (15.92)	
African American	23	42.43 (22.35)	E = 1.086	40.83 (21.93)	E = 1.252
Hispanic	19	32.53 (17.09)	E = 1.309	37.95 (16.77)	E = 1.606

Another way to examine research question 3 is to look at differences that might have occurred in proficiency levels. As reflected in Table 14 and Table 15, there were no non-proficient white students on either assessment. The group of white students who exhibited the most significant amount of change were the level fours, six of whom improved to level five, and two of whom regressed to level three. African American level four students were also mobile; one of six increased to level five while one decreased to level three. Hispanic students were the only group that saw the number of proficient students increase, going from 4 of 19 (21.1%) proficient to 7 of 19 (36.8%) proficient. Within this subgroup, there was also a level 4 student who moved to level 5. All groups experienced an increase at level five. However, white students experienced the most considerable change at this level, with half of all students performing at this level compared to 22.73% at the end of sixth grade. These data suggest that flipped instruction may positively affect the performance gap for Hispanic students, but not for African American students.

Table 14

EOG Proficiency Level and MOY Projected Proficiency Level by Ethnicity (Frequency)

EOG (MOY)	White	African American	Hispanic
Non-proficient	0	12 (12)	15 (12)
3	2 (4)	3 (4)	1 (4)
4	15 (7)	6 (4)	3 (2)
5	5 (11)	2 (3)	0 (1)

Table 15

EOG Achievement Level by Race (Percent)

	White	African American	Hispanic
Non-proficient	0%	52.17%	76.5%
3	9.09%	13.04%	5.9%
4	68.18%	26.08%	17.6%
5	22.73%	8.7%	0%

Based on the standardized test data, white student performance improved by 6.4% between the BOY and MOY, when flipped learning was the instructional method. The effect size for the comparison of means was 0.35053. Hispanic students also experienced an increase in scores, with a 16.7% increase in mean percentage correct from the BOY. The effect size for the comparison of means was 0.34146. As stated earlier, the mean percentage correct for African American students decreased between the beginning and midyear assessments after the flipped instruction. There was a 2.4% decrease in the mean percentage of correct scores. This decrease represents the smallest amount of change and the only group that showed a decrease in this instructional model. The effect size for this comparison was −0.11906.

Examination of student scores bears out reports of student mathematics performance by race. The MOY (after flipped instruction) mean correct percentage score for white students was 68, for African American students, 44.1, and for Hispanic students, 39.594. The BOY mean percentage correct for white students was 63.8824, for African American students, 45.2, and for Hispanic students, 33.8824. The BOY performance gap between white and African American students was 18.6824, and between white and Hispanic students was 30. After instruction with flipped instruction, the performance gap was 23.9 between white and African American students and 28.406 between white and Hispanic students. For African American students, the performance gap increased. However, the performance gap decreased for Hispanic students.

CHAPTER 5: CONCLUSIONS

This investigation focused on three research questions:

1. How does the use of the flipped learning instruction model affect teaching and learning in middle-grade classrooms?
2. How does the use of flipped learning instruction affect student engagement and motivation?
3. In what ways, if any, does flipped learning impact the "gaps" in student achievement?

This final chapter focuses on summarizing findings in response to each of the questions and then goes on to put the findings in context to explore how the use of flipped instruction impacted the teaching and learning of mathematics in this middle school.

Research Questions 1: How Does the Use of the Flipped Learning Instruction Model Affect Teaching and Learning in a Middle-grades' Classroom?

Teaching. An evaluation of the flipped learning model used in this study must consider both the way the model was implemented and the setting's Montessori environment. Although there are variations in "flipping a classroom," the most common is viewing instructional videos outside of class. In this study, students were permitted and encouraged to use class time to view the videos. This mode of implementation impacts how class time is being used and minimizes the possibility of seeing some of the benefits reported in prior studies. The use of authentic, rich tasks with a higher cognitive load and increased mathematical discourse are considered effective instructional practices and are often cited as benefits of flipped learning in mathematics (Bergmann & Sams, 2012; Finkel, 2012; Gorman, 2023; Hamdan et al., 2013). The engagement in authentic problem solving and the resulting mathematical discourse around that practice were not observed. The utilization of class time for viewing the direct instruction videos was likely related to why these practices were not observed. The Montessori setting of the school was also likely to be a factor.

The setting for the study was a public middle school; however, it was a Montessori magnet. School staff members have all been trained in Montessori methodologies. All the teachers in the study had completed graduate-level teacher training and held an American Montessori Society Secondary Teaching Credential. Much of the manner in which the flipped model in this case was implemented can be attributed to efforts to integrate Montessori methodologies. The use of class time for viewing the videos begs to question whether this instructional method is truly flipped instruction. Teachers, however, expressed that allowing students the choice of when and how to use the videos was consistent with the Montessori's student-centered, self-directed learning. And that the pre-recorded lessons, which students could access when and where they wanted, and as many times as needed, met the basic criteria for flipping.

In this case, the data show that students were most often engaged in independent tasks during the study. The viewing of the instructional videos and the notetaking associated with viewing videos had the second-highest frequency for all observed activities. Though teachers pre-recorded lessons, students most often viewed those lesson during class. Because required homework is not a part of the regular routine at this Montessori school, students were not required to view instructional videos outside of class. The practice of using class time for viewing of the videos, the means of direct instruction, negates some of the reported benefits of this instructional model. Student use of class time for viewing the lessons reduced opportunities for discourse, cooperative work on authentic tasks and other collaborative learning opportunities. The opportunities for the exploratory activities, or "shelf work' normally associated with

Montessori classrooms was also reduced as students devoted time to "worksheets" documenting that the lessons had been viewed and understood.

The use of hands-on manipulatives and the development of academic independence are crucial elements in Montessori mathematics training. Independent work time is a scheduled portion of nearly all school days. Though collaboration was allowed, the greater emphasis was on individual effort and self-regulation. The Montessori methodology also minimizes traditional "whole class" instruction, including prolonged large group discussion. The focus on self-paced, personalized instruction, also promoted in Montessori-based education, limits collaborative work opportunities and extended shared discussions of problem-solving processes.

These findings suggest that as implemented in this study, flipped learning does not support some of the highly effective instructional practices for mathematics teaching and learning, as recommended by NCTM, as stated previously. Using the MTPACK and RAT frameworks, as implemented, this model of flipped instruction does not represent an integration of technology. The use of technology for direct instruction replaces the non-technology-based lessons, and the Internet-based activity observed was identical to a paper and pencil activity students had done previously. There was no evidence of the use of technology to enrich or transform student learning.

One positive impact of the use of flipped learning relates to student-teacher interactions. Classroom observation data showed that teachers regularly engaged with students individually or in small groups. In the focus group and individual interviews, teachers reported having the opportunity to work with students one on one and in small groups in the flipped classroom than in a traditional classroom. They reported having a greater understanding of student abilities and needs because of the increased interactions. Teachers also stated that the use of prerecorded lessons was a vital management tool in their multi-age classrooms. Like most Montessori classrooms, the range of the ages of students allowed for a broad range of instructional needs. Because this is a public school, teachers and students are held accountable for grade level curriculums. Classrooms include students enrolled in three mathematics courses, who are in the same space but learning different curriculum. Prerecorded lessons, teachers stated, allow them to provide both curriculum-aligned instruction and personalized support for students simultaneously. Teachers reported that this structure was a vital part of their ability to have productive interactions with students.

In this case, the data indicated that the decision to utilize flipped instruction was heavily influenced by a need to manage the various curriculum levels being taught in their multi-age classrooms. The commitment to multi-age groupings is a part of the Montessori design based on student developmental levels and social needs. The focus of the school on Montessori design greatly influenced the way the flipped model was implemented. Evaluating the effect of the flipped model is complicated by the implementation of Montessori methodologies. Though some of the previously reported benefits related to authentic tasks, student interactions, and improved discourse were not evidenced, other benefits, such as increased teacher-student interactions, were observed.

Learning

To assess the impact of flipped instruction on student learning data from the sixth grade, EOG mathematics assessment were compared with the BOY Case 21 mathematics assessment and the MOY Case 21 mathematics assessment. As stated in Chapter 4, overall student scores improved from BOY to MOY, though the change was not statistically significant. An analysis by the subgroup showed that the mean scores of Hispanic students increased most, followed closely by white students' mean scores. Mean scores for African American students decreased. It is worth noting that scores for Hispanic students were significantly lower than those of white students and were also lower than those of African American students. The ability to replay video lessons may have been an essential factor for some Hispanic students. Given the constraints of this study, the examination of the causes of these differences was not possible. However, what is known is that services for language learners were provided for several Hispanic students in the study, and the ability to repeat and replay instruction would increase comprehension of instruction for those students.

Research Question 2: How Does the Use of Flipped Instruction Affect Student Engagement and Motivation?

Most current research identifies multiple dimensions related to engagement: behavioral, emotional, and cognitive (Wang et al., 2016). For this study, behavioral engagement was assessed based on participation in classroom activities, time on task, and community rules adherence. Emotional engagement was assessed based on student interest and reports of learning value. Cognitive engagement was assessed based on perseverance, the use of varying strategies to learn, self-monitoring, and understanding of the content. The overall assessment of engagement was based on a combination of these dimensions. The student engagement and motivation assessment utilized data from the classroom observations, student surveys, and the student focus group interviews.

Classroom observations provided the bulk of the behavioral engagement data. With only two exceptions, students were positively and actively participating in classroom activities during observations. Students responded to redirection by the teachers and were all in compliance with school and community behavioral expectations. These data support the presence of a high level of behavioral engagement during the study.

In the surveys and focus group interviews, students shared data about their level of interest in and enjoyment of the content, topics related to emotional engagement. Students indicated a clear preference for flipped lessons over traditional classroom instruction. They also reported that they learned better in the flipped model. In the surveys, 75% of students indicated that they were "good at math," a perception not based on the achievement data. Reports of reduced anxiety, increased ability to focus, and self-efficacy as a math student contribute to the data that suggest the flipped model improved emotional engagement in this study. Research has shown a relationship between self-efficacy and motivation in mathematics learning (Soland, 2019). The evidence of increased self-efficacy, combined with the classroom observation data, can be extrapolated to support increased motivation.

Cognitive engagement was demonstrated in data from the focus group interviews. Students reported behaviors demonstrating perseverance (i.e., watching and re-watching videos), self-regulation (i.e., pacing and choice of time/place for tasks), and use of various strategies for learning (e.g., work with a peer, ask the teacher, Khan Academy, shelf work). Students also indicated that they believed they were learning and understanding the content. Data support the existence of cognitive engagement. Cumulatively, it follows that the data in this study demonstrates high student engagement with the use of flipped instruction.

Research Question 3: In What Ways, If Any, Does Flipped Learning Impact the "Gaps" in Student Achievement?

Based on this study's data, flipped learning did not improve the learning gaps between white students and students of color. As implemented in this environment, the "achievement" gap between white students and African American students increased with flipped learning utilization. The achievement differences between white students and Hispanic students showed minimal improvement. Many of the students of color were below grade level or barely at grade level at the end of 6^{th} grade. In the traditional settings where flipped instruction showed some improvements in achievement gaps, grades and performance were of greater importance than they are in a Montessori setting. As implemented in this situation, flipped learning proved less successful academically for students of color than for white students.

Possible Interpretation of Results

Assessment of the impact of the implementation of flipped instruction, in this case, has proven complicated. The desired improvements in student achievement were not observed for most students. One cluster of students, where increases were observed, had other mitigating factors, such as additional direct instruction from a non-community teacher. High performing level four students saw improvements in their scores. However, most of these students participated in small group enrichment with the advanced math teacher several times per week. They were given additional direct instruction outside of the classroom in addition to what was provided to other students.

A cluster of students who started with the lowest scores also saw increases in their scores. It is reasonable to surmise that the ability to view the lessons without typical classroom distractions and repeat instruction as needed increased this group's understanding of concepts, and thus, increased their scores. One student in this category indicated as much in the focus interviews. As mentioned earlier, the language barrier made learning challenging for some of the Hispanic students for whom English proficiency was still growing. These students, as well, demonstrated growth with the flipped model's use and likely benefitted from being able to stop, rewind, and replay the instruction.

African American students at the extremes performed similarly to their peers in other subgroups; both the lowest- and highest-performing experienced increases in percent correct scores. The majority of students in this ethnic subgroup, however, experienced decreases in their performance scores. The interview data suggest that most students did not feel challenged by the work and felt no urgency in getting their work done. In addition, because of the inability to ask clarifying questions during the videos, and the hesitancy of students in this age group to “look dumb’, many students of color did not seek out assistance from the teacher and were content with their performance. The de-emphasis of traditional performance measures in Montessori schools, which were the only school environment known to most of these students, contributed to their lack of focus on performance. The task-focus of Montessori schools, as compared to the performance focus of traditional settings likely explains the disconnect between students believe in their ability and their achievement. Students indicated that they preferred utilizing flipped instruction for learning math and believed they were learning as much as in previous classrooms. The performance data did not support that perspective.

Areas for Further Study

This study occurred over four weeks with a small group of students. A more extensive study that lasted the length of an academic year would have been preferable. A comparison of EOG scores would have enabled the researcher to gauge performance increases or decreases more accurately and would have enabled a comparison to expected growth. Further study is also needed to explore some of the performance differences seen between subgroups. Of particular interest would be an exploration of the experiences of Hispanic students. They made modest gains, and understanding factors related to those gains would allow educators to boost this subgroup’s performance further. Additional study of the factors impacting performance for the African American subgroup is warranted. As a whole, this group saw scores decrease during the use of the flipped instruction model. Understanding the reasons for this decrease could help identify specific strategies to support students and minimize opportunity and achievement gaps.

The mode of implementation of flipped instruction used in this study, expecting students to view instructional videos during class time, was chosen to support the multi-age classroom environment necessitated by the adherence to the Montessori philosophy. Utilizing a model where students viewed instructional videos outside of the classroom would impact how in-class time is used and could provide opportunities to explore more of this instructional method's purported benefits. This study included a limited analysis of the resources used in addition to the instructional videos. A broader study of the specific resources and strategies used in implementation would refine an understanding of this instructional strategy's impact and effectiveness.

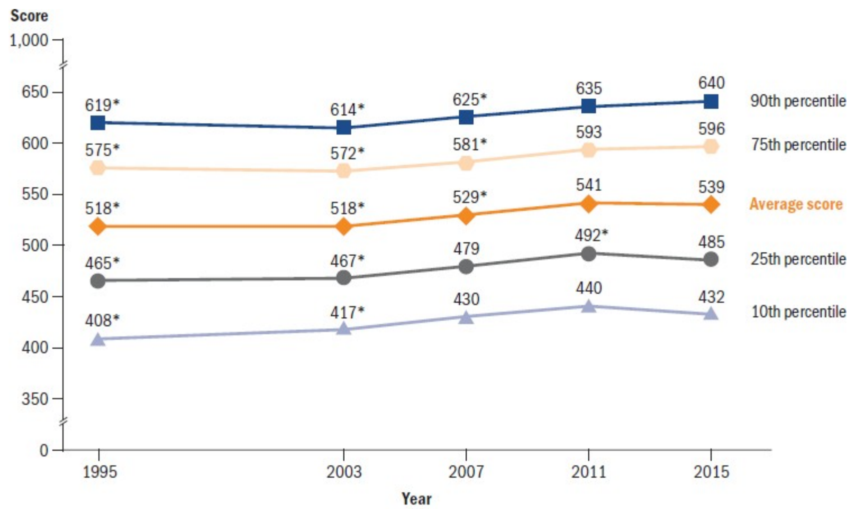
Though academic performance is a crucial component of evaluating educational practices, it is not the only component. In reviewing the impact of flipped instruction in a middle-grade mathematics classroom, both teachers and students positively reacted to this model. Student motivation and engagement were high, and teacher satisfaction with the model was also high. Future goals should include understanding how to increase academic performance for all students using the model and incorporating more research-based "effective practices" as part of the implementation.

The conclusion of this study occurred during a global pandemic. At the time of this writing, UNESCO reported, 1,579,634,506 learners, or 90.2% of total enrolled learners, have been affected by school closures. One hundred ninety-one countries had nationally mandated country-wide closures. In the United States, 43 states, 3 U.S. territories, and the District of Columbia ordered or recommended school building closures for a third of the academic year, affecting approximately 42 million public-school students. For most students, the closing of school buildings did not mean that learning for the academic year ceased. Many schools and districts adopted distance or remote learning as a means of continuing learning during the period of school building closure. This situation highlights the importance of understanding how to effectively utilize technology to help students learn. Numerous resources for teachers designed to support remote learning have become available in a brief amount of time. Prerecorded instructional videos are often one of the suggested tools. Though not the only component, prerecorded instructional videos are at the core of flipped instruction. This study of flipped instruction seems very timely, given that a greater understanding of how this model impacts teaching and learning can support the use of such technology-based practices in the future

APPENDIX A

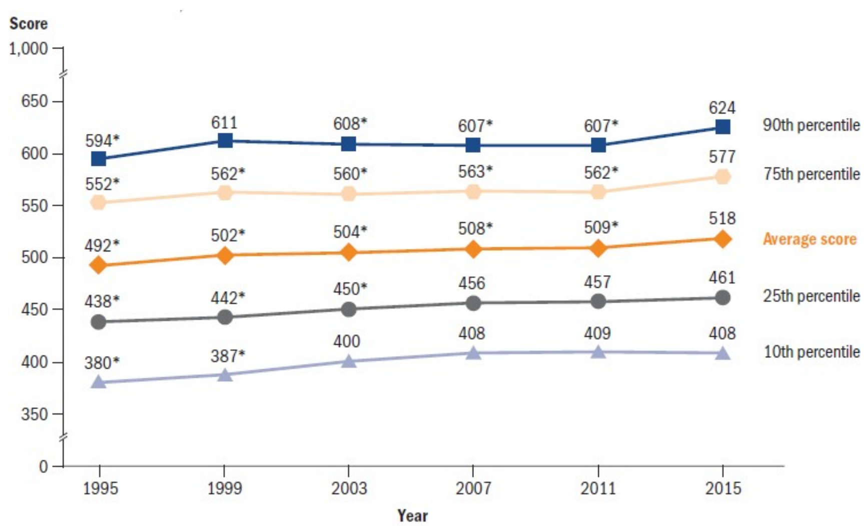
TIMMS Data

Trends in U.S. 4th-grade students' average mathematics scores and cut scores at the 10th, 25th, 75th, and 90th percentiles: 1995, 2003, 2007, 2011, and 2015



* Score is statistically different from the 2015 score ($p < .05$).
NOTE: TIMSS was not administered at the fourth grade in 1999. See appendix tables A1 and A2 for details on coverage and sampling issues in the United States for 2015 and earlier years, respectively.
SOURCE: International Association for the Evaluation of Educational Achievement (IEA), Trends in International Mathematics and Science Study (TIMSS), 1995, 2003, 2007, 2011, and 2015.

Figure A1. 2016 TIMMS data for fourth-grade students.



* Score is statistically different from the 2015 score ($p < .05$).
NOTE: See appendix tables A1 and A2 for details on coverage and sampling issues in the United States for 2015 and earlier years, respectively.
SOURCE: International Association for the Evaluation of Educational Achievement (IEA), Trends in International Mathematics and Science Study (TIMSS), 1995, 1999, 2003, 2007, 2011, and 2015.

Figure A2. 2016 TIMMS data for eighth-grade students.

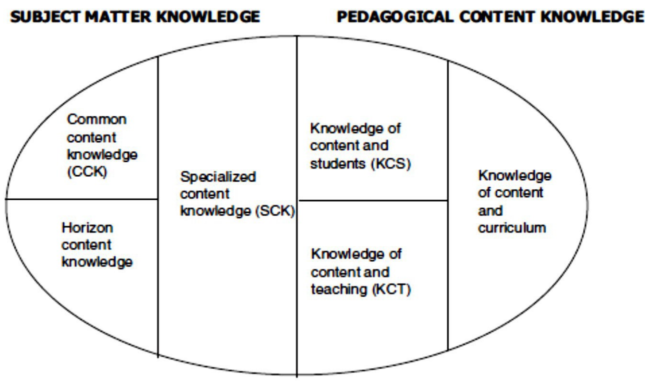


Figure A3. Domains of mathematical knowledge for teaching.

Table A1 represents their definitions for the different knowledge domains.

Table A1

Types of Knowledge for Mathematical Teaching

Domain Name	Definition
Common content knowledge (CCK)	mathematical knowledge and skill used in settings other than teaching.
Horizon content knowledge	awareness of how mathematical topics are related over the span of mathematics included in the curriculum
Specialized content knowledge (SCK)	mathematical knowledge and skill unique to teaching
Knowledge of content and students (KCS)	combines knowing about students and knowing about mathematics
Knowledge of content and teaching (KCT)	combines knowing about teaching and knowing about mathematics
Knowledge of content and curriculum	knowledge of the materials and programs that serve as "tools of the trade" for teachers

Figure 2

NCTM Effective Mathematics Teaching Practices

Establish mathematics goals to focus learning. Effective teaching of mathematics establishes clear goals for the mathematics that students are learning, situates goals within learning progressions, and uses the goals to guide instructional decisions.

Implement tasks that promote reasoning and problem-solving. Effective teaching of mathematics engages students in solving and discussing tasks that promote mathematical reasoning and problem solving and allow multiple entry points and varied solution strategies.

Use and connect mathematical representations. Effective teaching of mathematics engages students in making connections among mathematical representations to deepen understanding of mathematics concepts and procedures and as tools for problem-solving.

Facilitate meaningful mathematical discourse. Effective teaching of mathematics facilitates discourse among students to build a shared understanding of mathematical ideas by analyzing and comparing student approaches and arguments.

Pose purposeful questions. Effective teaching of mathematics uses purposeful questions to assess and advance students' reasoning and sense-making about important mathematical ideas and relationships.

Build procedural fluency from conceptual understanding. Effective teaching of mathematics builds fluency with procedures on a foundation of conceptual understanding so that students, over time, become skillful in using procedures flexibly as they solve contextual and mathematical problems.

Support productive struggle in learning mathematics. Effective teaching of mathematics consistently provides students, individually and collectively, with opportunities and supports to engage in productive struggle as they grapple with mathematical ideas and relationships.

Elicit and use evidence of student thinking. Effective teaching of mathematics uses evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning.

Table A2

Organization of NCTM Teaching Practices

Framework of Instructional Practices	*PtoA* Teaching Practices
Ensuring student engagement in learning (Communication)	Facilitating meaningful mathematical discourse Pose purposeful questions Support productive struggle in learning mathematics Elicit and use evidence of student thinking
Understanding the content; focusing on what students are to learn, understand, and be able to do with their knowledge (Mathematical Knowledge)	Establish mathematical goals that focus learning Implement tasks that promote reasoning and problem solving Build procedural fluency from conceptual understanding
Making the connections; elucidating the connections between various representations (Transfer)	Use and connect mathematical representations

Levels of Math Talk Learning Community: Teacher and Student Action Trajectories				
Components of the Math Talk Learning Community				
Teacher Role	Questioning	Explaining mathematical thinking	Mathematical representations	Building student responsibility within the community
Overview of shift among Levels 0-3: The classroom community grows to support students' acting in central or leading roles and shifts from a focus on answers to a focus on mathematical thinking				
Shift from teacher as leader of conversation to students/teacher as co-leaders.	Shift from teacher as questioner to students and teacher as questioners.	Students increasingly explain and articulate their math ideas.	Students increasingly explain their math thinking relying, as needed, on math drawings/ representations.	Students increasingly take responsibility for learning and evaluation of others and self. Math sense becomes the criterion for evaluation.
Level 0: Traditional teacher directed classroom with brief answer responses from students				
Teacher is at the front of the room and dominates conversation.	Teacher is only questioner. Questions serve to keep students listening to teacher. Students give short answers and respond to teacher only.	Teacher questions focus on correctness. Students provide short answer-focused responses. Teacher may tell answers.	Representations are missing or teacher shows them to students.	Students believe they need to keep ideas to themselves or just provide answers when asked.
Level 1: Teacher beginning to pursue student mathematical thinking. Teacher plays central role in the Math Talk Community				
Teacher encourages sharing of math ideas and directs speaker to talk to the class, not to the teacher only.	Teacher questions begin to focus on student thinking and less on answers. Only teacher asks questions.	Teacher probes student thinking somewhat. One or two strategies may be elicited. Teacher may fill in an explanation. Students provide brief descriptions of their thinking in response to teacher probing.	Students learn to create math drawings to depict mathematical thinking.	Students believe their ideas are accepted by the classroom community. They begin to listen to each other supportively and to restate in their own words what another student said.
Level 2: Teacher modeling and helping students build new roles. Some co-teaching and co-learning begins as student-to-student talk increases. Teacher physically begins to move to the side or back of room.				
Teacher facilitates conversation between students, and encourages students to ask question of one another.	Teacher asks probing questions and facilitates some student-to-student talk. Students ask questions of one another with prompting from teacher.	Teacher probes more deeply to learn about student thinking. Teacher elicits multiple strategies. Students respond to teacher probing and volunteer their thinking. Students begin to defend their answers.	Students label their math drawings so others are able to follow their mathematical thinking.	Students believe they are math learners and that their ideas and the ideas of classmates are important. They listen actively so that they can contribute significantly.
Level 3: Teacher as co-teacher and co-learner. Teacher monitors all that occurs, still fully engaged. Teacher is ready to assist, but now in more peripheral and monitoring role (coach and assister).				
Students carry conversation themselves. Teacher only guides from the periphery of the conversation. Teacher waits for students to clarify thinking of others.	Student-to-student talk is student initiated. Students ask questions and listen to responses. Many questions ask 'why' and call for justification. Teacher questions may still guide discourse.	Teacher follows student explanations closely. Teacher asks students to contrast strategies. Students defend and justify their answers with little prompting from the teacher.	Students follow and help shape descriptions of others' math thinking through math drawings and may suggest edits in others' math drawings.	Students believe they are math leaders and can help shape the thinking of others. They help shape others' math thinking in supportive, collegial ways and accept the same.

Hufferd-Ackles, Fuson and Sherin (2016) adapted from two versions of Hufferd-Ackles, Fuson, and Sherin (2004, 2015) from joint communication S. Friel with authors January 2016.

Figure A4. Math Talk framework.

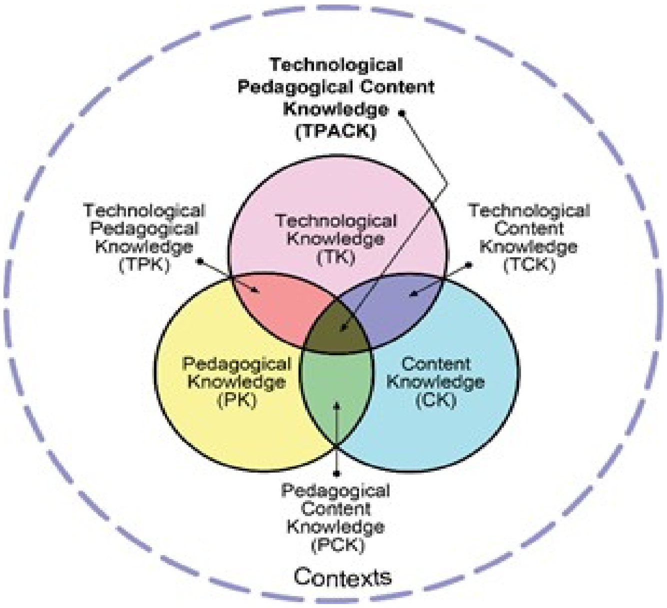


Figure A5. TPACK framework.
Note. Adapted from Mishra and Koehler, 2006.

Table A3

Dimensions (Within Themes) for Guiding Analysis of Technology Use

Instructional Methods	Student Learning Processes	Curriculum Goals
	… include...	
Teachers role Interaction with students Professional development Preparation Administrative tasks	Activity task Thinking process-mental process Task milieu (individual, small group, whole-class, others) Motivation Student attitude	"Knowledge" to be gained, learned, or applied "Experience" to be gained, learned, or applied

Note. (Hughes, Thomas & Scharber, 2006).

Table A4

NCTM Effective Teaching Strategies and RAT Model

		Integration of Technology Use from RAT Framework		
		Replacement Description: “Involves technology used to replace and, in no way, change established instructional practices, student learning processes, or content goals” (p. 2).	Amplification Description: “Use that amplified current instructional practices, student learning, or content goals. Increased efficiency and productivity are major effects” (p. 2).	Transformation Description: Through comparison with pencil/paper or something that is newly possible, “Use that transforms the instructional method, the students’ learning processes, and/or the actual subject matter” (p. 3).
Research-Informed Teaching Practices from Principles to Action: Ensuring Mathematical Success for All (NCTM, 2014)	Establish Mathematics Goals to Focus Learning Description: *Establish clear goals for the mathematics that students are learning, situates goals within learning progressions and uses the goals to guide instructional decisions (p. 10).*			
	Implement Tasks That Promote Reasoning and Problem Solving Description: *Engage students in solving and discussing tasks that promote mathematical reasoning and problem solving and allow multiple entry points and varied solution strategies (p. 10).*			
	Use and Connect Mathematical Representations Description: *Engage students in making connections among mathematical representations to deepen understanding of mathematics concepts and procedures and as tools for problem-solving (p. 10).*			
	Facilitate Meaningful Mathematical Discourse Description: *Facilitate discourse among students to build a shared understanding of mathematical ideas by analyzing and comparing student approaches and arguments (p. 10).*			

	Pose Purposeful Questions Description: *Use purposeful questions to assess and advance students' reasoning and sense-making about important mathematical ideas and relationships (p. 10).*			
	Build Procedural Fluency from Conceptual Understanding Description: *Build fluency with procedures on a foundation of conceptual understanding so that students, over time, become skillful in using procedures flexibly as they solve contextual and mathematical problems (p. 10).*			
	Support Productive Struggle in Learning Mathematics Description: *Consistently provide students, individually and collectively, with opportunities and supports to engage in productive struggle as they grapple with mathematical ideas and relationships (p. 10).*			
	Elicit and Use Evidence of Student Thinking Description: *Use evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning (p. 10).*			

Note. (Hughes, Thomas & Scharber, 2006)

APPENDIX B:

Teacher Interview Protocol

1. I would like to know a bit more about the students in this class.

    Tell me about the ability levels of students in this class.

    How do they compare to students in the schoolas a whole?

    Are there any students with special needs in this class?

    Are there any students for whom English is not their first language?

    Are there any students with learning disabilities?

2. Is student absenteeism or mobility a problem for you in this class?

3. What resourcesdid you use to plan this unit?

4. Were these resources/materials/activities designated for this class/course, or did you choose to use them yourself? What criteria did you use for selecting resources?

5. What do you like about these resources/materials/activities?

What do you not like? What might you do differently if you teach this unit again?

6a. *If the lesson was based on one resource/material:*

Did you plan this unit essentially as a text, organized it, or modify it in meaningful ways?

6b. *If the lesson was based on more than one resource:*

Did you plan this unit essentially as it was organized by any one of the texts or materials, or did you modify it in significant ways?

7. Can you describe the modification you made and your reasons for making them?

8. Do you use the same instructional materials in videos that are provided to students in the classroom?

9. How do the instructional resources affect video content?

10. What guided your decisions about how the flipped instruction was to be used?

11. What planning goes into the making of the videos used with your students? How much time does it take to make a video?

12. How do you evaluate the quality or effectiveness of the instructional videos?

13. How do you monitor student viewing of the videos?

14. Are students able to complete classroom activities without viewing instructional videos?

15. Are videos differentiated, or are they the same for all students within a specific course?

16. How do you feel about teaching with the flipped classroom strategy?

  How comfortable do you feel using the instructional strategies involved in teaching this lesson?

  How did you decide to use this instructional strategy?

  What opportunities have you had to learn about using these strategies?

  Have you taken classes that used this model? How did you feel about those classes?

  Do you know of other teachers outside your building using flipped instruction to teach middle school mathematics? If so, have you had an opportunity to collaborate with them?

17. How many years have you been teaching prior to this year?

18. Have you taught this unit before?

If yes: How different was today from how you have taught it previously?

Is there anything about this particular group of students that led you to plan this unit this way?

19. What about your teaching situation influenced your planning and implementation of this unit?

20. Did the facilities, available equipment, or supplies influence your choice of how you taught this unit?

APPENDIX C:

Student Survey Protocol

Student Survey

Please indicate how much you agree or disagree with each of the following statements:

	Question	Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
1.	I prefer video lessons to traditional classroom lessons					
2.	I learn better with videos than I do from traditional classroom lectures.					
3.	Watching videos outside of class makes class time more engaging.					
4.	I have access to technology that lets me view the videos outside of school.					

Do you consider yourself "good at math?" Why or why not? Do you enjoy learning math?

Of the past ten videos, how many did you watch?

Student Interview Protocol

Student Interview Protocol

1. Tell me about this flipped classroom for math. How does it work?

2. How did the work in this unit differ from what you are used to in math class?

3. Which do you like better? Why?

4. There were_________videos to watch in this unit. If you did not watch all the videos, what was the reason?

5. What was good about the videos? What was not so good about the videos?

6. What was/is your favorite part of math class during this unit? Why? What was your least favorite? Why?

7. Do you watch other web-based instructional videos? For what subject(s)? How often? How did you find those videos?

8. Is there anything else you would like to share?

APPENDIX D:

IRB Documents

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

OFFICE OF HUMAN RESEARCH ETHICS

720 Martin Luther King, Jr. Blvd. Bldg. 385, 2nd Floor

CB #7097

Chapel Hill, NC 27599-7097
(919) 966-3113

Web site: ohre.unc.edu

Federalwide Assurance (FWA) #4801

To: Raelysha Butler James and Rita O'Sullivan School of Education Deans Office

From: Office of Human Research Ethics

Date: 8/02/2019

RE: Notice of IRB Exemption
Exemption Category: 1. Educational setting

Study #: 19-1776

Study Title: Technology and mathematics teaching and learning; using flipped instruction to teach middle school mathematics

This submission, Reference ID 249192, has been reviewed by the Office of Human Research Ethics and was determined to be exempt from further review according to the regulatory category cited above under 45 CFR 46.104.

Study Description:

Purpose: The purpose of this study is to investigate how the use of flipped instruction impacts the teaching and learning of mathematics in a middle-grades classroom.

Participants: The participants are teachers and seventh-grade students in a local public middle school.

Procedures (methods): The intent of the study is to observe classrooms during an instructional unit and to assess the impact of the instructional methods on students. Instructional videos, classroom activities, and teacher lesson plans will be reviewed. In addition, teachers and students will be interviewed to obtain their perspectives on flipped instruction.

Investigator's Responsibilities:

If your study protocol changes in such a way that exempt status would no longer apply, you should contact the above IRB before making the changes. There is no need to inform the IRB about changes in study personnel. However, be aware that you are responsible for ensuring that all members of the research team who interact with subjects or their identifiable data complete the required human subjects training, typically completing the relevant CITI modules.

The IRB will maintain records for this study for three years, at which time you will be contacted about the status of the study.

The current data security level determination is Level II. Any changes in the data security level need to be discussed with the relevant IT official. If data security level II and III, consult with your IT official to develop a data security plan. Data security is ultimately the responsibility of the Principal Investigator.

Dear Parents:

My name is Raelysha Butler James, and I am the Community 1 Math and Science teacher at Lakewood Montessori Middle School. I am currently pursuing my doctoral degree in Curriculum and Instruction at the University of North Carolina at Chapel Hill School of Education under the direction of Professor Rita O'Sullivan. I am conducting a research study to understand the effects on student engagement, motivation, and achievement that technology use has in seventh-grade math students. Our sixth-grade mathematics classrooms utilize traditional instructional delivery, and our seventh and eighth-grade classrooms utilize "flipped" instruction where students use teacher recorded videos for direct instruction. My goal is to investigate student reactions to and impressions of the flipped model.

I am inviting your child's participation, which will involve allowing me to interview your student and make observations during their math classes with the possibility of being chosen at random for participation in a focus group. Your child's participation in this study is voluntary. Your child may decline participation in a focus group and speaking with me at any time. There will be no penalty or discomfort, and it will not affect your child's grade.

Although there may be no direct benefit to your child, the possible benefit of your child's participation in the study include a better understanding of effective instructional strategies, and this information may be used to make decisions regarding mathematics teaching and learning in our district. There are no foreseeable risks or discomforts to your child. This information may assist in making changes to technology innovations to better suit the needs of all students in Durham Public Schools.

All data collection will be anonymous, and no forms of identifying information will be requested. If your child volunteers to participate in a focus group, it will be recorded. The recording will only be heard by the researchers involved in the study and will not be made public. Students will provide their first names only for the focus group. Due to the nature of focus groups, complete confidentiality may not be able to be maintained. However, no questions will be asked that may be sensitive in nature, and the recordings will be destroyed upon the completion of the study. The results of this study may be used in reports, presentations, or publications, but your child's name will not be used.

If you have any questions concerning the research study or your child's participation in this study, you may e-mail me at Raelysha.butlerjames@dpsnc.net or call Principal Warnele Carmon at (919) 560-2894.

Sincerely,

Raelysha Butler James, M.Ed.

By signing below, you are giving consent for your child ________________ (Child's name) to participate in the above study. Please identify your child's level of participation.

Signing here means that you consent for your child to participate in one focus group interview.

______________________________	______________________________	____________
Signature	Printed Name	Date

Signing here means that you consent for your child to be audiotaped during the focus group interview.

______________________________	______________________________	____________
Signature	Printed Name	Date

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